STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

AN EVALUATION OF FIBERGLASS AND STEEL REINFORCED ELASTOMERIC BRIDGE BEARING PADS

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16. ABSTRACT

The results of tests conducted on 1-1/2" thick reinforced neoprene bridge bearing pads having shape factors of 3, 6, 9 and 12 are presented herein. The tests included compressive stress versus strain, creep, translation and ultimate compressive strength. Test pads included samples laminated with steel reinforcement and samples laminated with fiberglass reinforcement at 1/2 inch intervals. Test pads fabricated from 50 and 60 durometer neoprene were used. All tests were conducted at room temperature.

Compressive stress versus strain data is presented for pads with shape factors of 3, 6, 9 and 12. Shear modulus data are presented for shape factors of 6 and 9.

Data from the ultimate compressive strength and translation tests indicate that steel reinforced pads can withstand higher loadings than the fiberglass reinforced pads.

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CONVERSION FACTORS

English to Metric System (SI) of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in)or(")	25.40 .02540	millimetres (mmm) metres (m)
	feet (ft)or(')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.432×10^{-4}	square metres (m^2)
	square feet (ft^2) acres	.09290 .4047	square metres (m^2) hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	.02832	cubic metres (m^3)
	cubic yards (yd^3)	.7646	cubic metres (m^3)
Volume/Time			
(Flow)	cubic feet per second (ft^3/s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph) feet per second (fps)	.4470 .3048	metres per second (m/s) metres per second (m/s)
Acceleration	feet per second squared (ft/s^2)	.3048	metres per second squared (m/s^2)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s^2)
Weight Density	pounds per cubic (lb/ft^3)	16.02	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs) kips (1000 lbs)	4.448 4448	newtons (N) newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb) foot-kips (ft-k)	1.356 1356	joules (J) joules (J)
Bending Moment or Torque	inch-pounds (ft-lbs) foot-pounds (ft-lbs)	.1130 1.356	newton-metres (Nm) newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch ($ksi\sqrt{in}$)	1.0988	mega pascals $\sqrt{metre}$ ($MPa\sqrt{m}$)
	pounds per square inch square root inch ($psi\sqrt{in}$)	1.0988	kilo pascals $\sqrt{metre}$ ($KPa\sqrt{m}$)
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{tF - 32}{1.8} = tC$	degrees celsius (°C)

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INTRODUCTION

Reinforced elastomeric bridge bearing pads have been successfully employed in California for many years. These elastomeric pads have demonstrated the ability to accommodate a wide range of compressive forces, rotations and translations, as well as the extreme environmental conditions that are found in California. As a result, reinforced elastomeric bridge bearing pads have established an outstanding track record of never having a bearing type failure on any of California's many structures which could be directly traceable to the reinforced elastomeric bearing pads themselves.

The successful use of any bearing pad is naturally contingent upon the use of adequate and reliable design criteria, such as the maximum allowable compressive stress (both live and dead) and maximum allowable horizontal translation.

Although present design criteria used in California is satisfactory and provides an adequate safety factor, advancements in the methods of fabrication as well as overall knowledge in the area of elastomers warrants a reevaluation of elastomeric bridge bearing pads with respect to current design practices and manufacturing techniques.

The basic objective of this research was not one of reinventing the wheel, but one of updating existing information based on present day manufacturing techniques and material used in bearing pad construction.

In order to accomplish this, full size elastomeric bridge bearing pads were tested to develop new compressive stress vs strain relationships, ultimate strength and creep characteristics of both steel reinforced and fiberglass reinforced pads.

BACKGROUND

Previous research conducted in 1974 by the California Transportation Laboratory (TransLab) investigated the compressive stress vs strain, compressive creep, ultimate strength in compression and translation characteristics of full size elastomeric bridge bearing pads of different thicknesses and shape factors(1).

Tests were conducted on both steel reinforced and fiberglass reinforced pads. Information provided by this previous research is presently being used by the California Department of Transportation (Caltrans) in the design of bridge bearing pads.

Since this initial research study, little has been done in the way of updating the design criteria. Several changes have evolved over the past years with regard to the manufacturing of elastomeric pads. Such items as the thickness of the steel reinforcement, fiberglass reinforcement locations, better bonding techniques, etc., have prompted a need to reevaluate certain properties of full size elastomeric bridge bearing pads with respect to these present manufacturing practices.

In order to successfully evaluate the present day steel reinforced and fiberglass reinforced bearing pads, it was decided to test full size bearing pads manufactured by two well known suppliers. By conducting tests on full size pads rather than small laboratory test specimens, design information obtained would relate better to the actual product.

A unique opportunity presented itself during this research project in that the Elastomers Division of E. I. duPont deNemours and Company, Inc., the sole producer of chloroprene rubber (neoprene), wished to update its technical literature on elastomeric bridge bearing pads(2). This technical literature had served over the years as the basis for design specifications presented in the Standard Specifications for Highway Bridges of the American Association of State Highway and Transportation Officials (AASHTO) and others (Caltrans included). In order to obtain information for their use, DuPont invited Caltrans to participate in the testing program as the information obtained would be beneficial to both DuPont and Caltrans. In exchange for test data generated by Caltrans, DuPont made arrangements with two main suppliers of reinforced elastomeric bearing pads to furnish the necessary bearing pads for testing. Basically, supplier number (1) would furnish the steel reinforced pads and supplier number (2) fiberglass reinforced pads. In addition to these pads, Caltrans also purchased some additional steel reinforced pads produced by supplier number (2) for comparative testing.

CONCLUSIONS

The following conclusions are based on tests conducted on steel reinforced and fiberglass reinforced elastomeric bridge bearing pads manufactured in accordance with Caltrans specifications as presented in the Appendix of this report. All pads were reinforced at 1/2 inch thickness intervals with either 14 gage steel or with fiberglass having an ultimate strength of 800 pounds per inch per ply.

1. The compressive stress vs strain characteristics of the fiberglass reinforced pads indicated a slightly higher relative stiffness than that of the steel reinforced pads. This difference apparently was due to the assumptions used in determining the effective thickness of the elastomer layers. This effective thickness is discussed later in this report.

2. The ultimate compressive strength of the steel reinforced bearing pads was in excess of 10,000 psi for both manufacturers.

3. The mode of failure for all ultimate strength tests was one of yielding of the steel or tensile failure of the fiberglass reinforcement.

4. Creep due to a sustained compressive load of 2,000 psi following initial strain of the steel reinforced pads was projected to be approximately 20% of the initial deflection at time = 10 years for the 50 durometer neoprene bearing pads tested. This is slightly less than the creep shown in the previous 1974 study (see discussion later in report).

5. Translation testing consisting of 10,000 cycles of ± one-half the total neoprene thickness showed no signs of failure of the steel reinforced pads when tested at 800, 1,000 and 1,200 psi compressive loadings. This was true for both manufacturers and both hardnesses tested.

6. The shear modulus for the steel reinforced pads when translated 100% of their thickness was found to be approximately 125 psi for compressive loads of 800, 1,000 and 1,200 psi for the 60 durometer neoprene and 107 psi for the 50 durometer neoprene.

7. The ultimate compressive strength of the fiberglass reinforced pads was approximately 1,800 psi.

RECOMMENDATIONS AND IMPLEMENTATION

The results of this research study will be supplied to the Caltrans Office of Structures Design as a means of updating their design criteria. In addition, it is recommended that consideration be given to increasing the allowable dead load + live load combination for steel reinforced bearing pads from the current 800 psi to 1,000 psi. It is not recommended that the existing design load of 800 psi for fiberglass reinforced bearing pads be increased.

GENERAL DISCUSSION

Since the specific objective of this research project was to update existing information pertaining to full size elastomeric bridge bearing pads, test parameters were selected which would allow for the collection and comparison of test data involving the least amount of variables.

° From our (Caltrans) earlier research (1974)(1) it had been shown that the compressive stiffness of the pads was not dependent on the pad thickness as such. It was decided, therefore, that rather than investigating a range of pad thicknesses, testing should be limited to one basic thickness of pad.

A pad thickness containing 1-1/2 inches of neoprene reinforced by either steel or fiberglass at 1/2 inch intervals, was, therefore, selected for the test program. This is a thickness that is commonly used.

° The thickness of all steel reinforcing plates for all sizes of pads was selected as 14 gage material. Even though the 14 gage plate may not have been required for the lower shape factors in order to assure parallel alignment during fabrication, it did represent the most typical steel plate thickness presently being used by the manufacturers in the range of shape factors we wished to investigate.

° Only two hardnesses of neoprene were selected to be investigated. These were Shore durometer hardnesses (Type A) of 50 and 60. The intent was to evaluate the pads of these two hardness levels in order to obtain data which reflected a 10 point variation. However, due to the allowable tolerances in the manufacturing of the neoprene, the pads actually supplied were closer to 52 and 57, or a five point spread.

° Four shape factors were selected for testing in order to develop a family of curves. These four shape factors, 3, 6, 9 and 12, were supplied in both steel reinforcement and fiberglass reinforcement for both the 50 and 60 hardnesses.

The basic size for the various shape factors were as follows:

SF	Length	Width
3	6-3/4	5-3/4
6	21-3/4	8-3/4
9	22-3/4	16-3/4
12	23-3/4	23-3/4

DESCRIPTION OF TEST SPECIMENS

The shape factor is a commonly used parameter used to predict the compressive stress vs strain behavior of neoprene bearing pads. By definition, the shape factor is the loaded surface area divided by the total free area allowed to move between reinforcements.

$$SF = \frac{W \times L}{2(W + L)t}$$

Where SF = Shape factor

W = Reinforced width

L = Reinforced length

t = Thickness of neoprene between reinforcements

In determining the shape factor for both steel reinforced and fiberglass reinforced bearing pads, certain assumptions were made with regard to the two different types of pad construction. These assumptions can best be pointed out by referring to a cross section of each pad (see Figures 1 and 2).

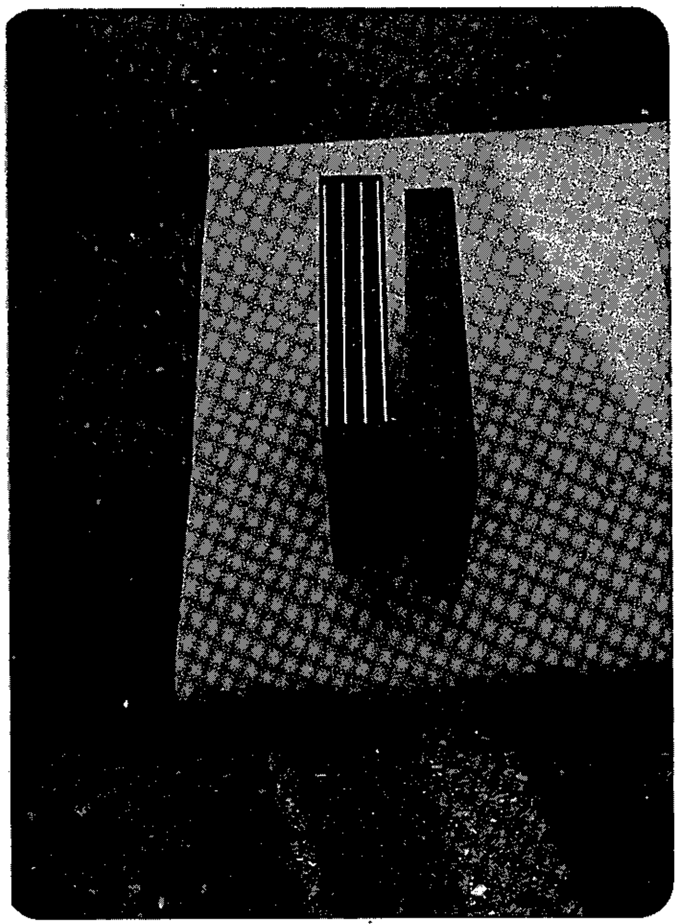
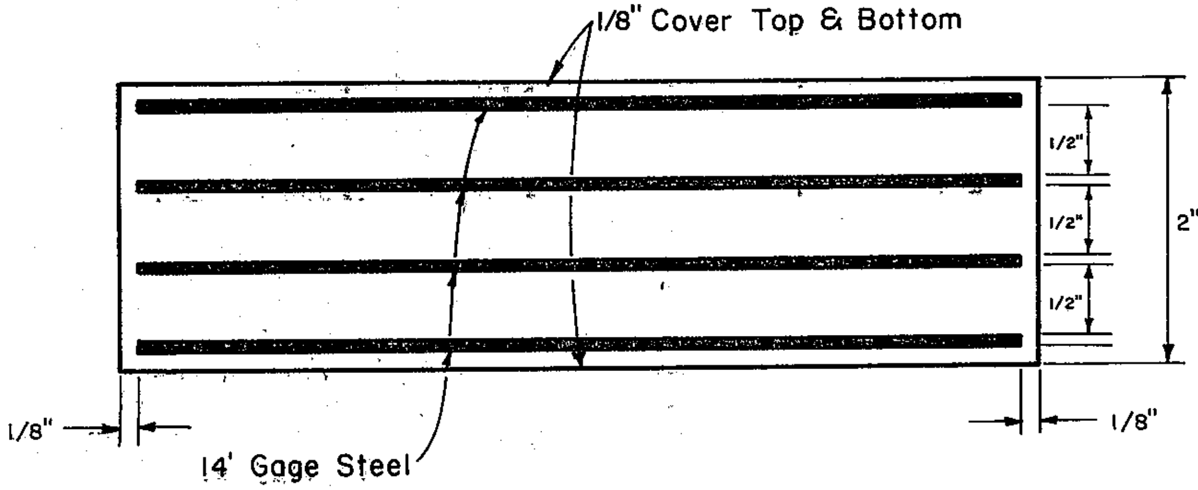
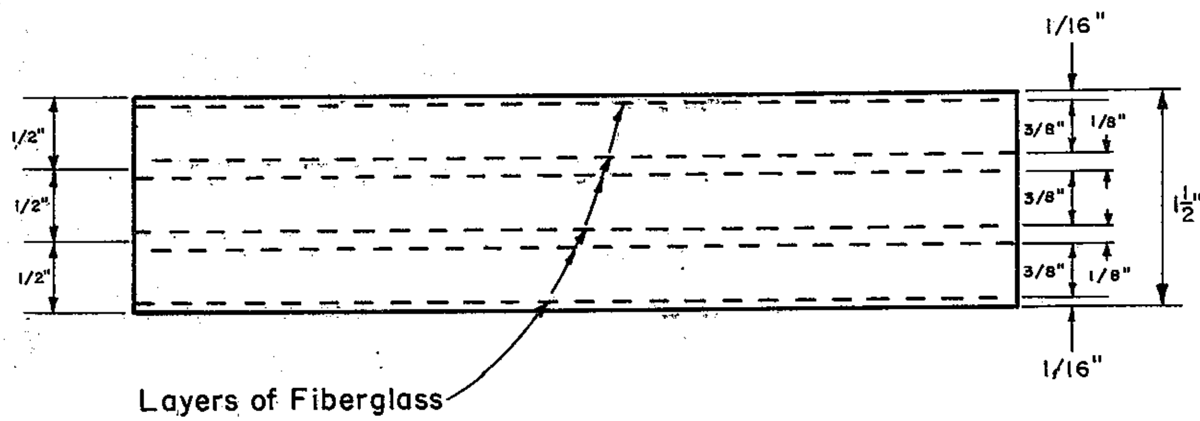


Figure 1. Reinforcement of Bearing Pads

°As shown in Figures 1 and 2, the steel reinforced pads consisted of basically three layers of 1/2 inch thick neoprene separated by 14 gage steel plate material with a plate at top and bottom also. The outer steel plates were covered with a 1/8 inch thick layer of neoprene. These steel pads were fully molded with a 1/8 inch thick covering of neoprene on all four sides. This outer covering serves basically as a corrosion protection for the steel plate material.



STEEL REINFORCED



FIBERGLASS REINFORCED

TYPICAL STEEL AND FIBERGLASS PAD CROSS SECTIONS

FIGURE 2

In calculating the shape factor for the steel reinforced pads, only the net surface area of the steel reinforcement was used. The thickness of the neoprene between the steel reinforcement was taken at t = 1/2 inch. The outer 1/8 inch covering top and bottom was neglected as far as the stress vs strain calculations were concerned.

° The fiberglass reinforced pads consisted of basically three layers of neoprene each 3/8 inch thick with a layer of fiberglass top and bottom covered by an additional 1/16 inch of neoprene (total 1/2 inch). When these three 1/2 inch layers are combined together, the resulting pad reflects a single layer of reinforcement top and bottom, with a double layer of reinforcement at 1/2 inch intervals.

Since the fiberglass requires no corrosion protection, no reduction in the surface area was made when calculating the different shape factors. Also, the thickness of the fiberglass was neglected and an "effective" thickness "t" was taken as 1/2 inch per layer.

Because of the basic differences in the construction of the two types of pads, the overall thicknesses were different, but the total effective thickness of the neoprene was the same (1-1/2 inches).

There were two main differences between the reinforced bearing pads used in the 1974 study and those used in this study.

1. The 1974 steel reinforced bearing pads utilized 20 gage mild steel shims with a yield strength of approximately 36,000 psi. This research study utilized 14 gage steel shims with a yield strength of approximately 40,000 psi.

2. The 1974 fiberglass reinforced bearing pads consisted of the same general design as shown in Figure 2 except that the separation between the interior double layers of fiberglass was 1/16" rather than the present 1/8".

The effect of the thicker gage steel reinforcement (shims) and the higher yield strength steel resulted in a higher compressive stress of the steel reinforced pads before yielding of the steel (2,500 psi± in 1974, 6,000 psi± today).

The effect of the greater separation between the double layers of fiberglass reinforcement in this study had little affect on the ultimate compressive strength of the fiberglass reinforced pads.

COMPRESSIVE STRESS VS STRAIN

Compressive stress vs strain measurements were made on both the steel reinforced and fiberglass reinforced elastomeric bearing pads representing theoretical hardnesses of 50 and 60 durometer.

The tests were conducted on a 1,000,000 pound capacity, electrohydraulic universal testing machine with a remote console for programming loading schedules (see Figure 3).

Two basic test set ups were used during the series of compressive stress vs strain tests. For those bearing pads with a shape factor of 3, the loading was applied through the top and bottom 20 inch diameter compression heads of the testing machine. Square steel plates 2 inches thick were placed on the top and bottom of the bearing pad to provide a smooth bearing surface as well as provide sufficient clearance for the placement of the deflection measuring devices (see Figures 4 and 5).

Deflection readings were measured using four dial indicators with accuracy to the nearest 0.001 inch mounted on the test fixture adjacent to the corners of the bearing pad.

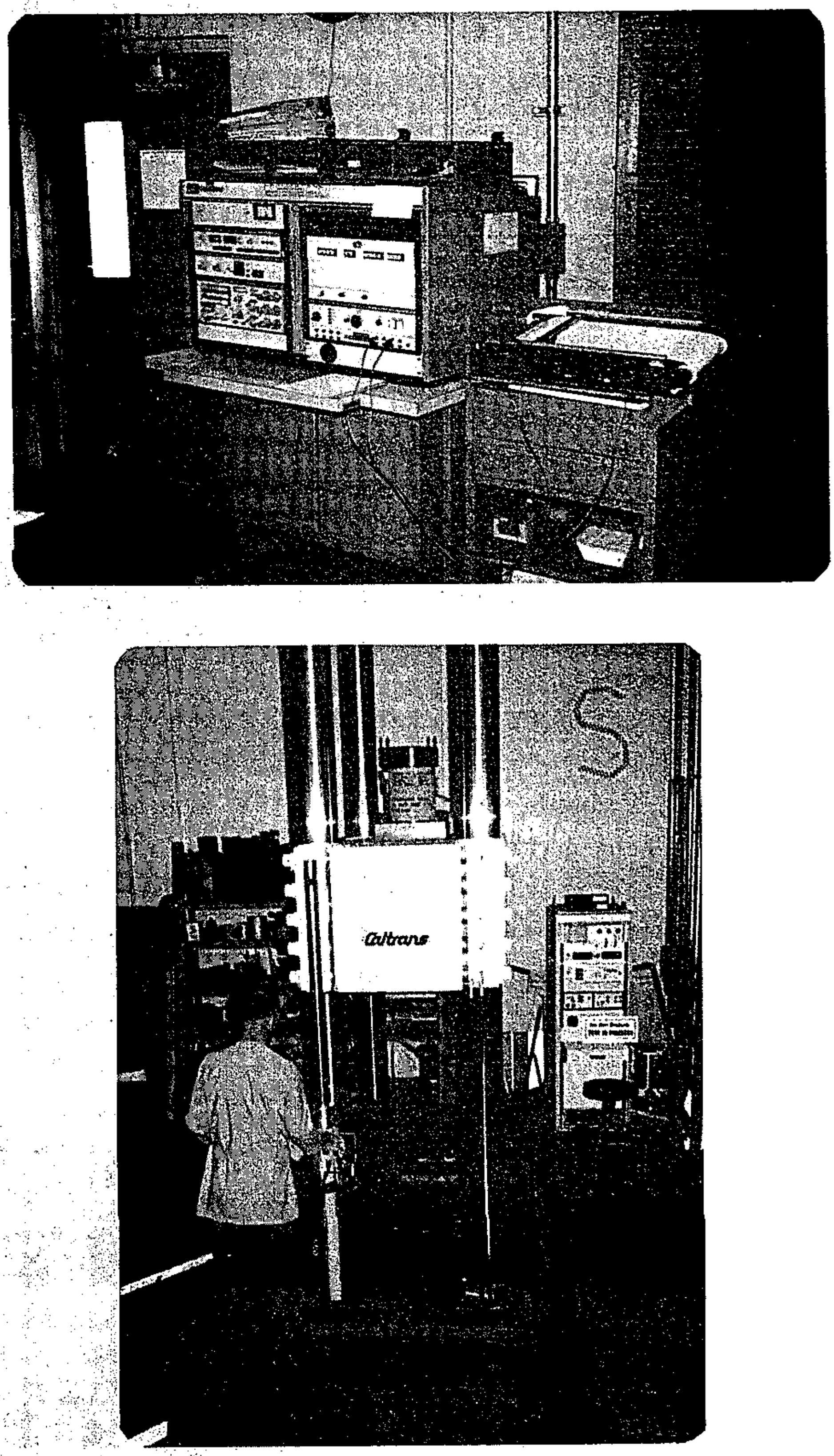
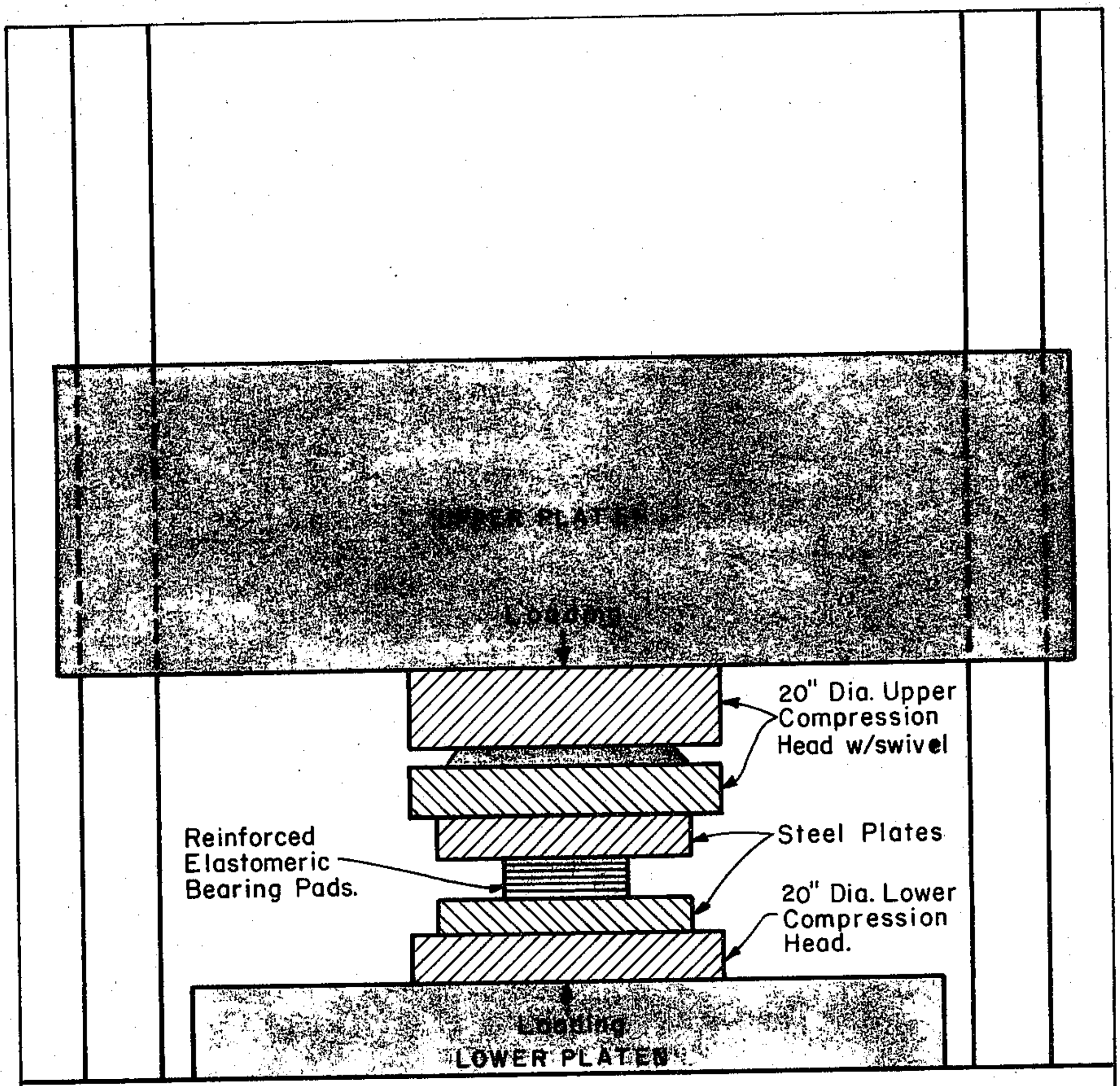


Figure 3. 1,000,000 Pound Testing Machine and Console



TYPICAL COMPRESSION TEST FOR SHAPE FACTORS 3

FIGURE 4

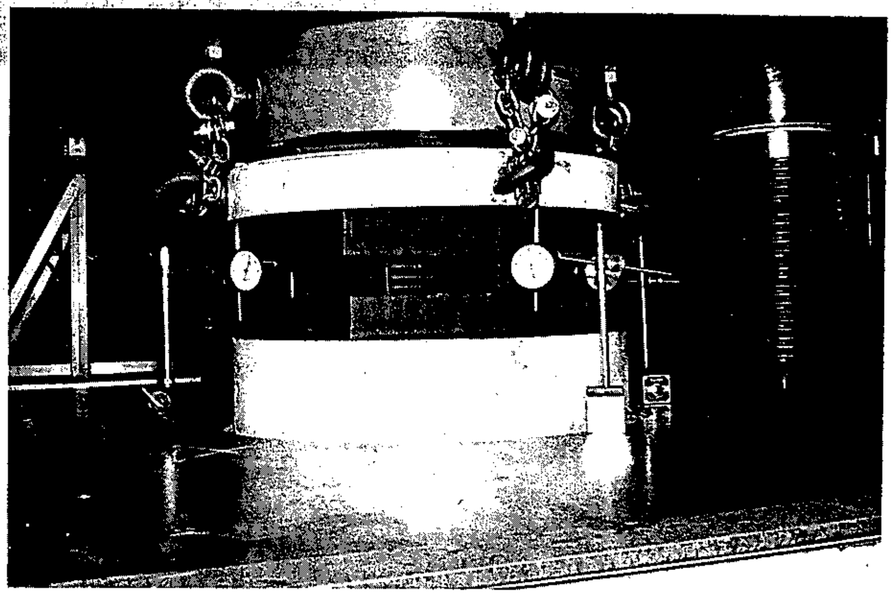


Figure 5. Typical Compression Test
For Shape Factor 3

For those bearing pads with shape factors 6, 9 and 12, it was necessary to distribute the load uniformly over the entire pad area. In order to accomplish this, it was necessary to utilize the test set up shown in Figures 6 and 7A. Again the dial indicators were placed near the corners of the bearing pad (see Figure 7B).

The actual procedure used during the compressive stress vs strain testing consisted of the following:

1. Center the pad between the upper and lower compression heads of the 1,000,000 pound testing machine.

2. Apply a preload of 50 psi.

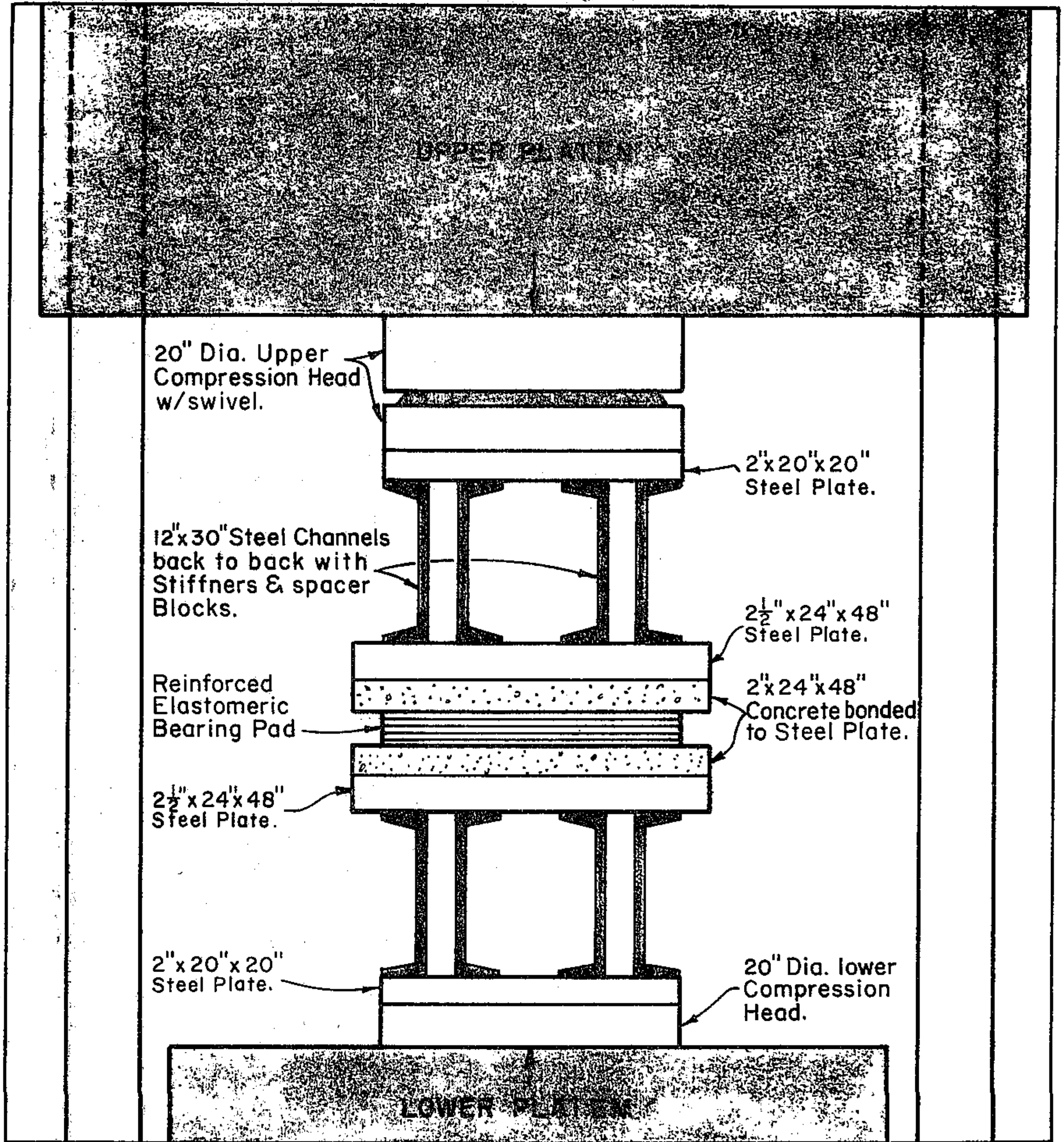
3. Zero all dial indicators.

4. Apply loads in 200 psi increments at a rate of 30 kips per minute.

5. At each 200 psi increment, hold load for 30 seconds; then read and record the four dial indicators.

6. For the steel reinforced bearing pads, continue loading at 200 psi increments until total loading reached 3,000 psi, or until the capacity of the testing machine has been reached.

7. For the fiberglass reinforced bearing pads, continue loading at 200 psi increments until total loading reached 2,000 psi, or until the pad failed.



TYPICAL COMPRESSION TEST FOR SHAPE FACTORS 6, 9 AND 12

FIGURE 6

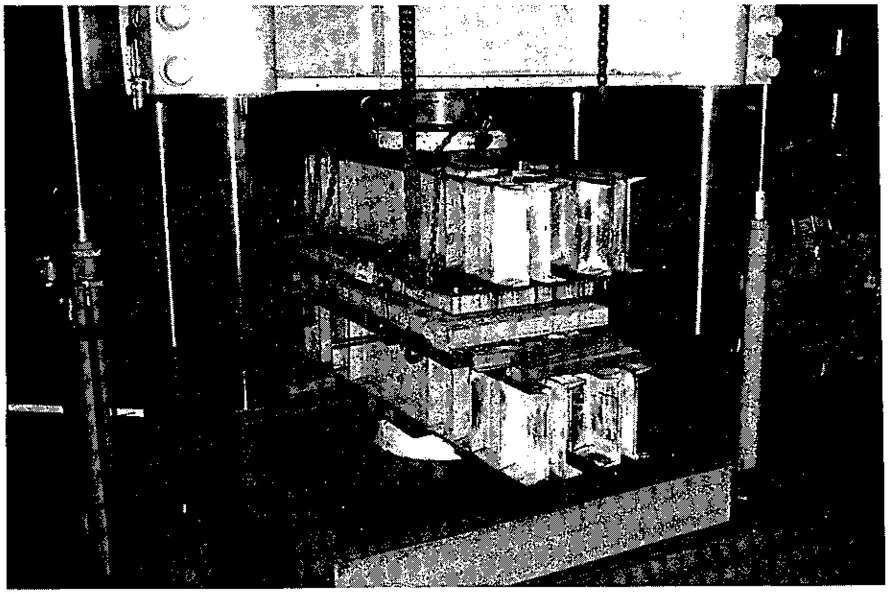


Figure 7A. Typical Compression Test For Shape Factors 6, 9 and 12

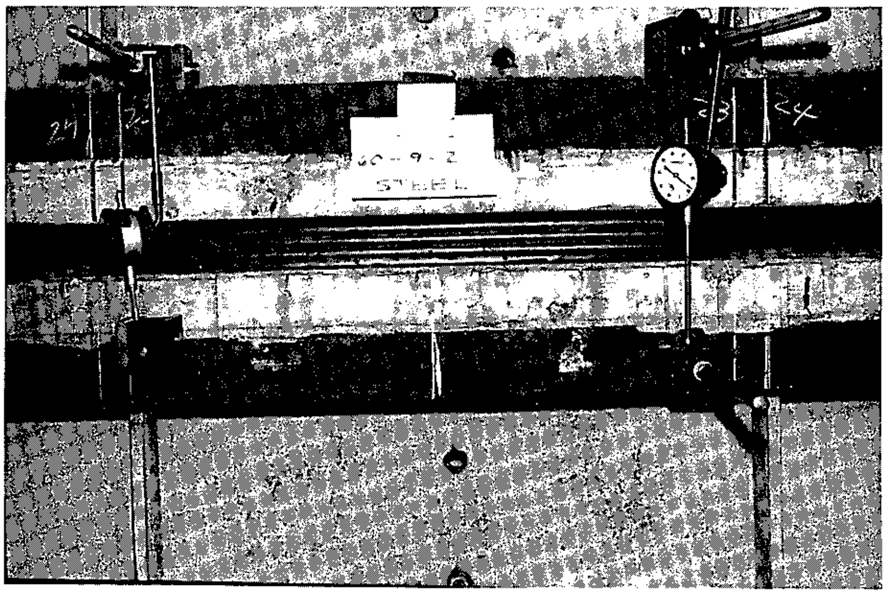


Figure 7B. Test Setup Showing Location of Dial Gages

In computing the strain, the same thickness (1-1/2 inches) was used for both the fiberglass reinforced and steel reinforced bearing pads tested.

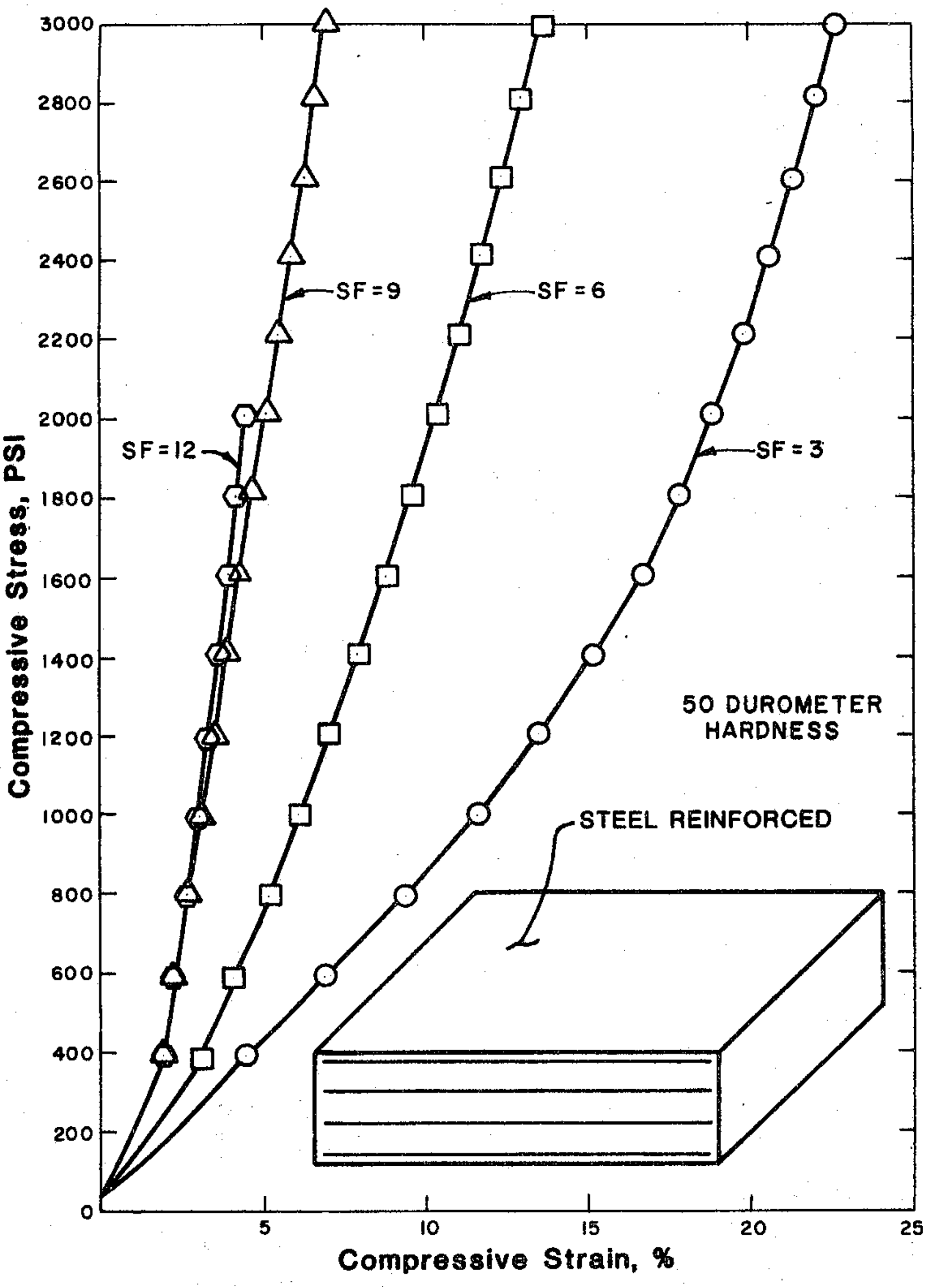
Test Results

The results of the compressive stress vs strain tests conducted on the various pads are shown in Figures 8, 9, 10, 11 and 12.

As seen by these figures, there was only a slight variation in the compressive stress vs strain curves of the fiberglass and steel reinforced pads for any given shape factor and hardness, with the biggest variation occurring with the shape factor of 3.

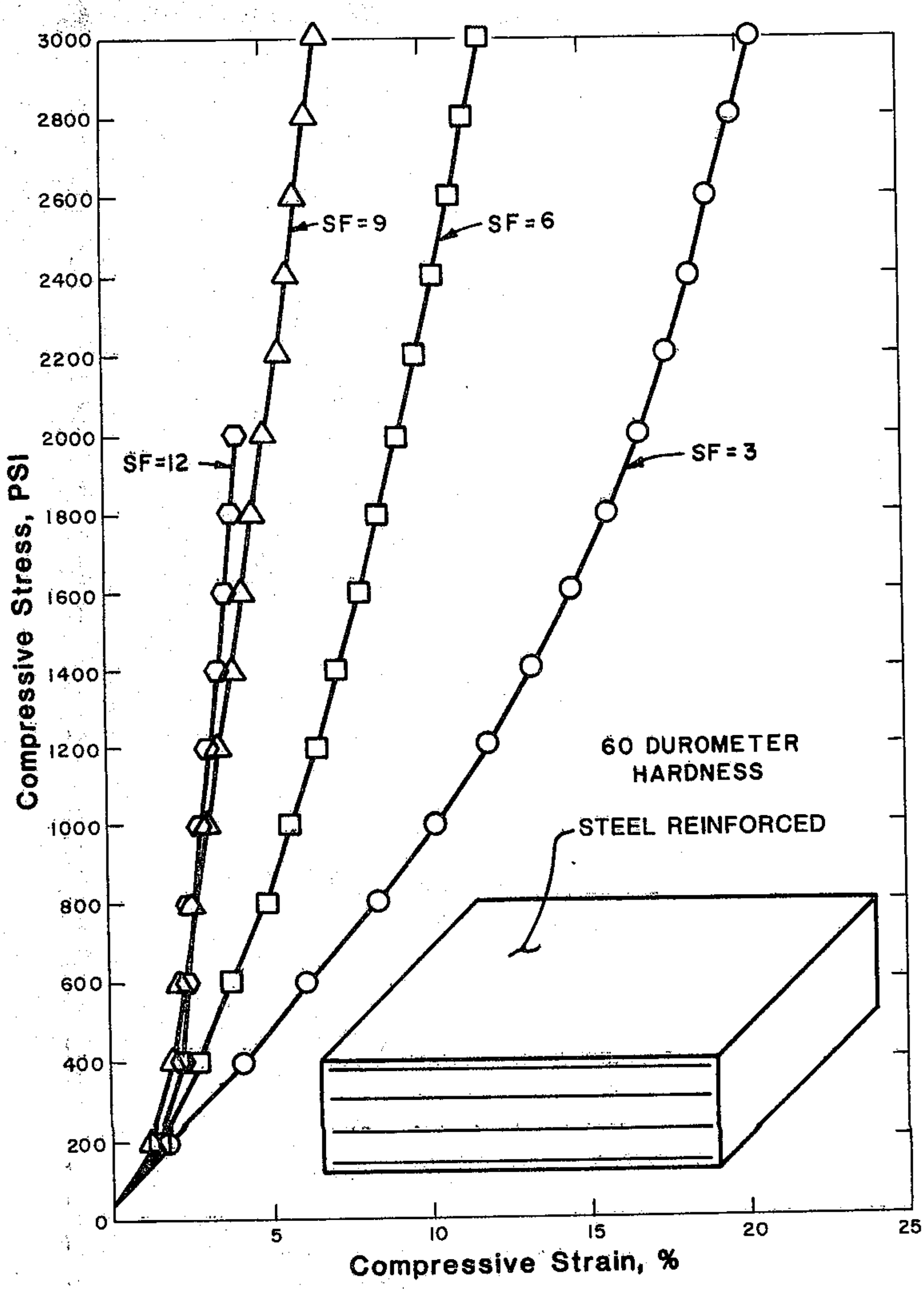
Discussion

During the loading of the different bearing pad samples, care was taken to assure that the pads were being loaded uniformly. Each pad was carefully centered (see Figure 13) and then the upper compression head of the testing machine was brought into contact with the bearing pad and the swivel head allowed to align itself until uniform contact with the pad was obtained. Metal spacers were then inserted between the swivel and the upper head to prevent the ball and socket from rotating during the test. This assured that a portion of the pad would not be overloaded as a result of the head rotating.



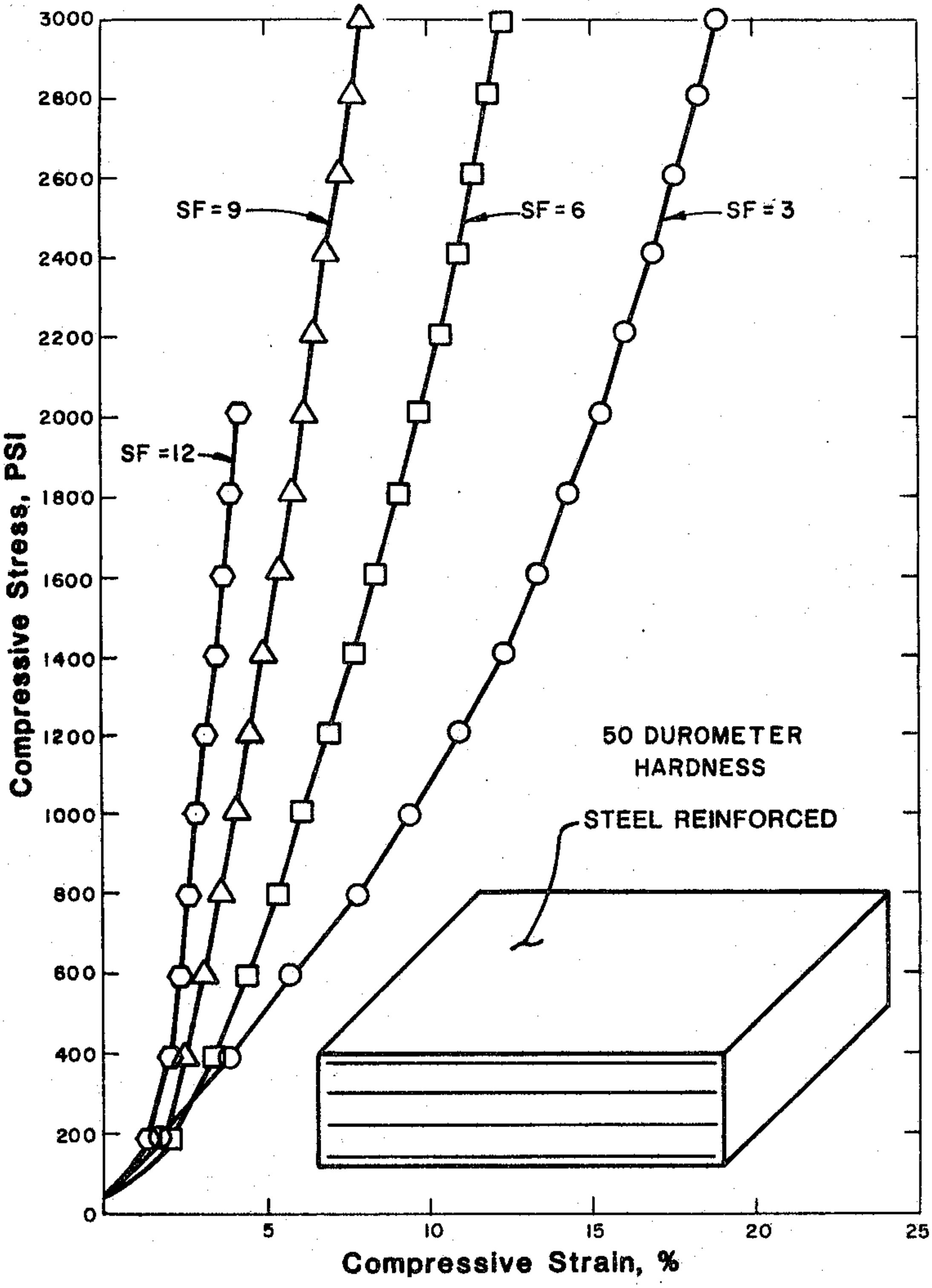
STRESS-VS-STRAIN
STEEL REINFORCED PADS
SUPPLIER No. 1

FIGURE 8



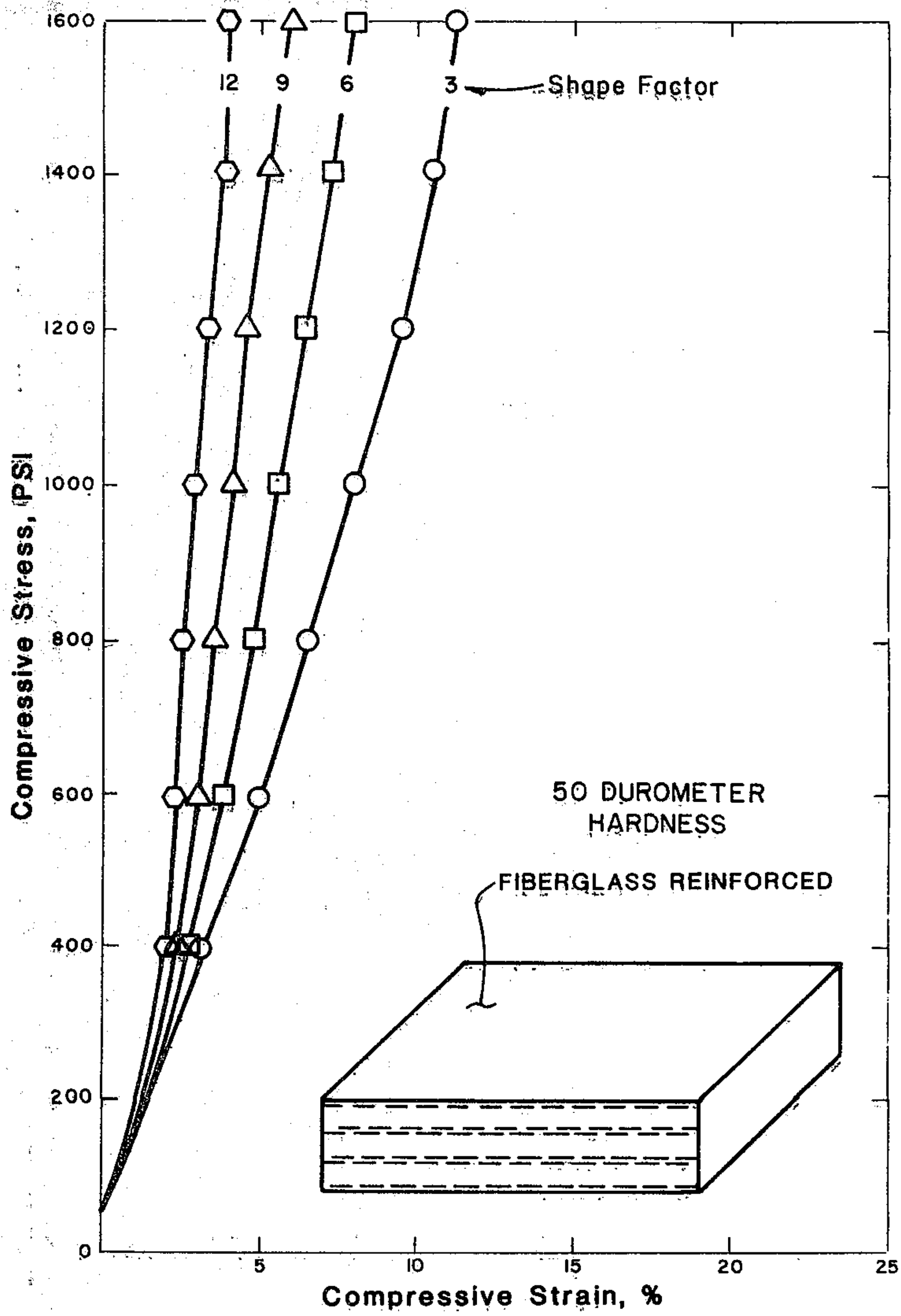
STRESS-VS-STRAIN
STEEL REINFORCED PADS
SUPPLIER No. 1

FIGURE 9



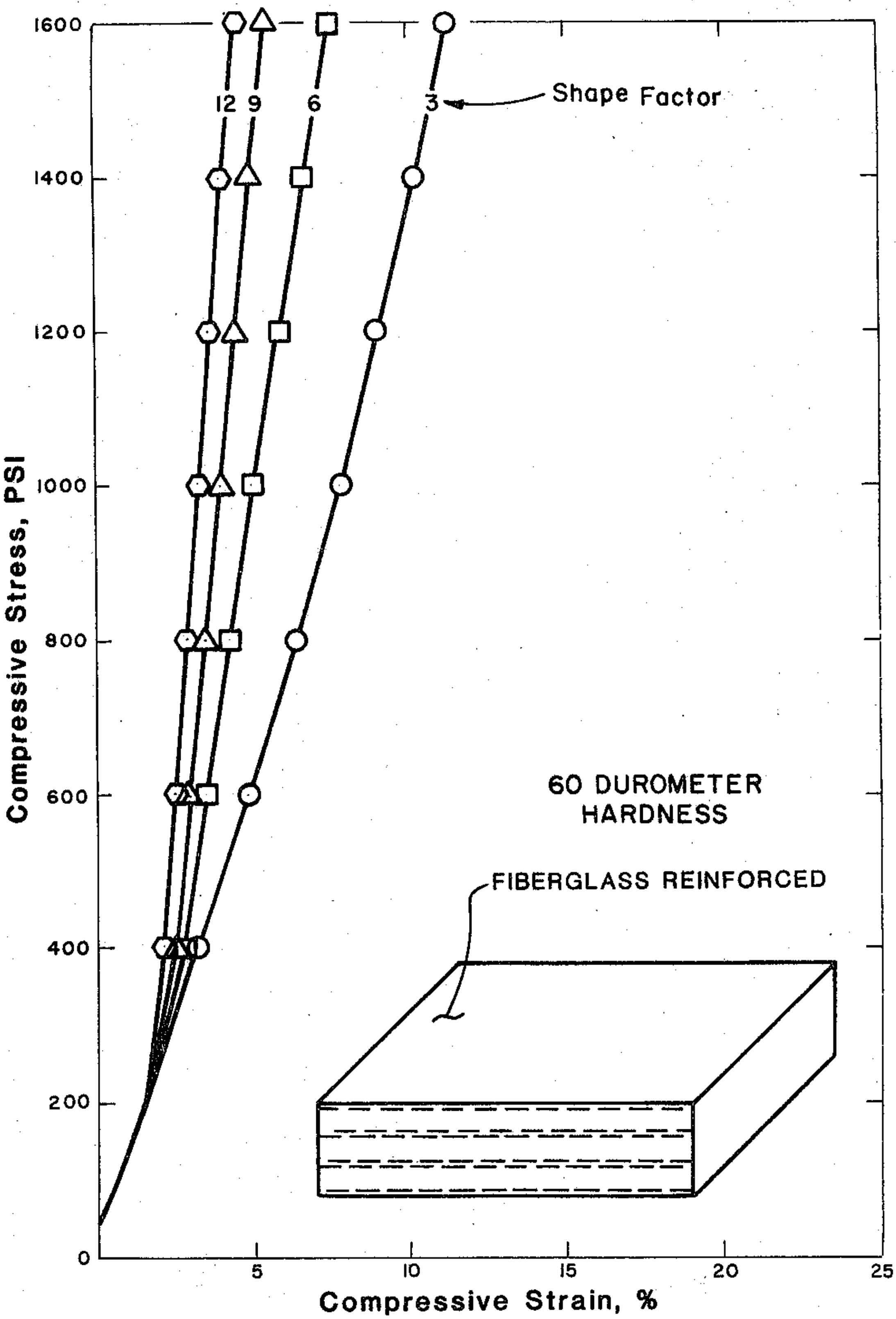
STRESS-VS-STRAIN
STEEL REINFORCED PADS
SUPPLIER No. 2

FIGURE 10



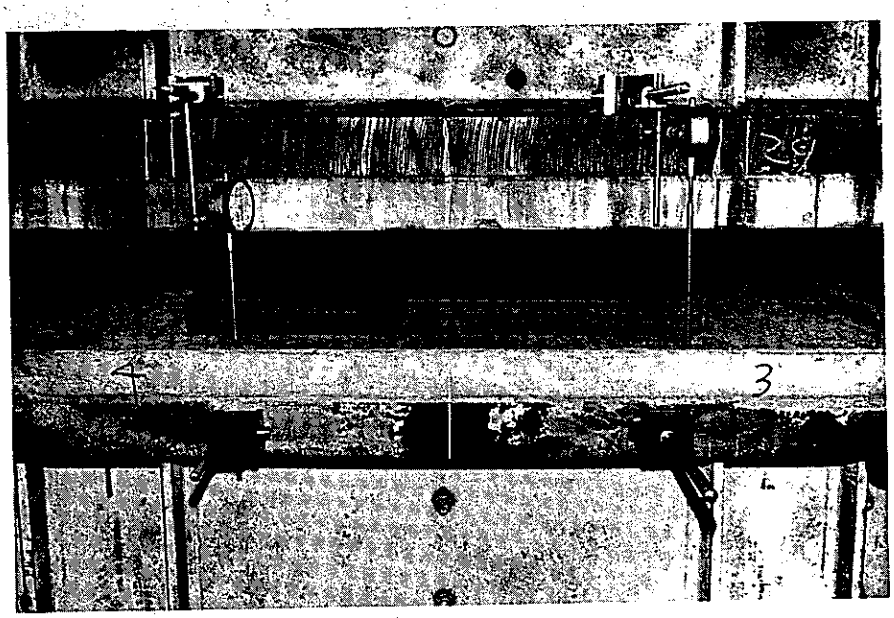
STRESS VS STRAIN
FIBERGLASS REINFORCED PADS
SUPPLIER No. 2

FIGURE 11



STRESS VS STRAIN
FIBERGLASS REINFORCED PADS
SUPPLIER No. 2

FIGURE 12



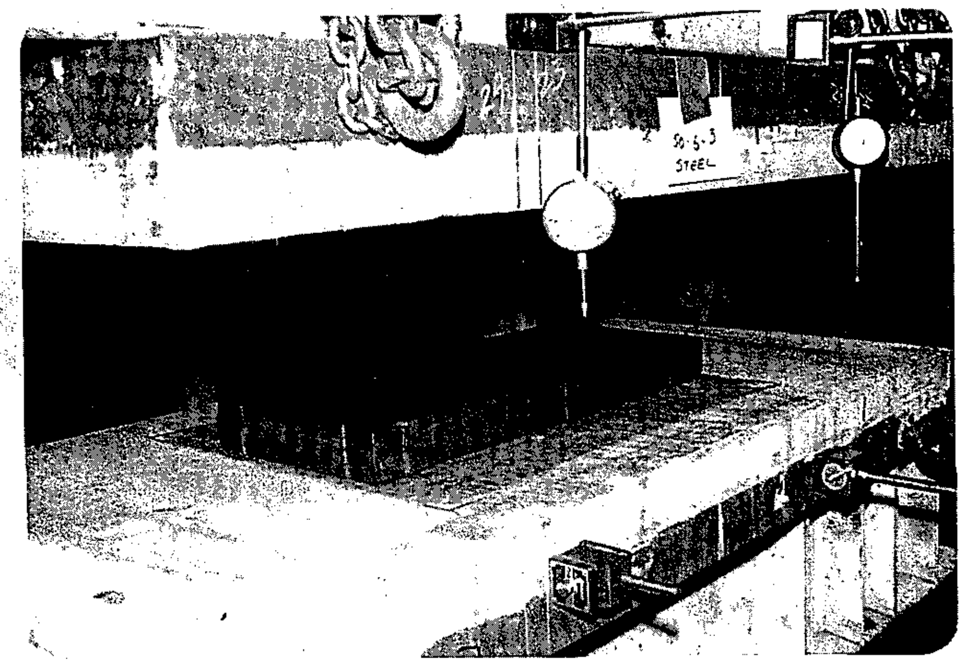


Figure 13. Centering of bearing Pads Prior to Testing

The compressive stress vs strain curves (Figures 8 through 12) represent the average of three test specimens for each shape factor and hardness. In addition, the percent of compressive strain was computed using the average of the four dial indicators used to monitor deflection of the pads tested. The readings from the four dial indicators showed good correlation during the test runs which reflects the uniform loading of the bearing pads.

In calculating the percent strain for the different pads, a total thickness of 1-1/2 inches of neoprene was used. It should be noted that the presented data will change slightly if the top and bottom 1/8 inch thick covering on the steel reinforced bearing pads is included in the strain calculations. It was felt, however, that because these thin outer layers are basically corrosion protection for the steel reinforcement, their effect on the overall strain of the pad could be safely neglected from a design standpoint.

Development of Recommended Design Curves

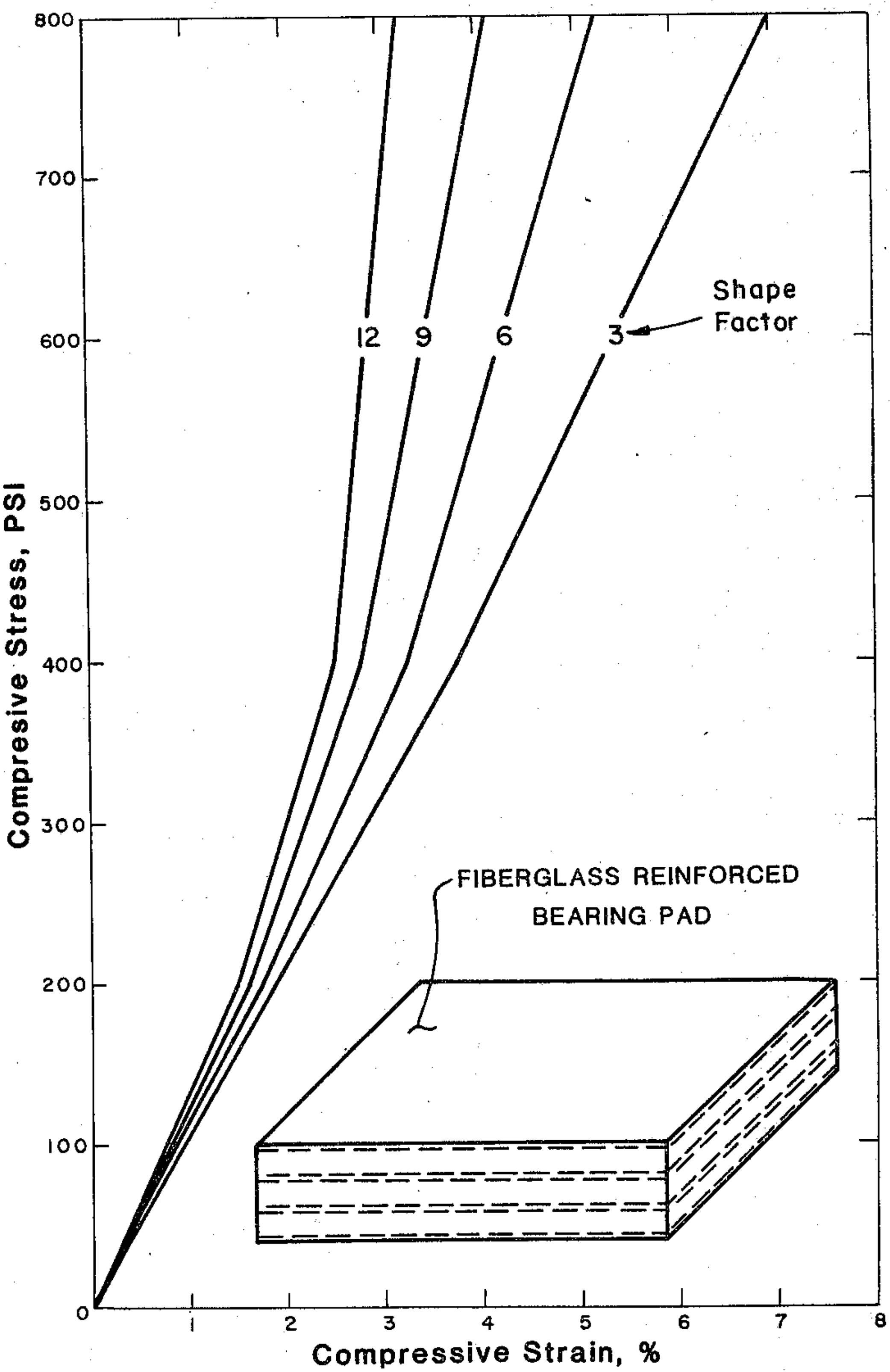
As previously shown in Figures 8, 9, 10, 11 and 12, the data generated from these many tests represent a wide range of compressive loadings. Although these various curves represent an accurate summary of data, they nevertheless are somewhat impractical from a design point of view due to the scale represented and the limited number of shape factors shown.

In order to obtain a more useful form for the design engineer, these curves were combined into basically two sets. The first (Figure 14) represents the compressive stress vs strain for the fiberglass reinforced pads, while the second (Figure 15) represents the steel reinforced pads. The curves were developed to 800 psi for the fiberglass reinforced pads since this is the present design limit. For the steel reinforced pads, the curves were plotted to 1,200 psi because of the possibility of increasing the allowable loading.

Although there was some difference in the overall stress vs strain curves of the steel reinforced bearing pads of 50 and 60 durometer (Figures 8, 9 & 10), the portion of the curves up to 1,200 psi was only slightly different. For this reason, it was felt that a single set of design curves could be developed to represent the steel reinforced pads.

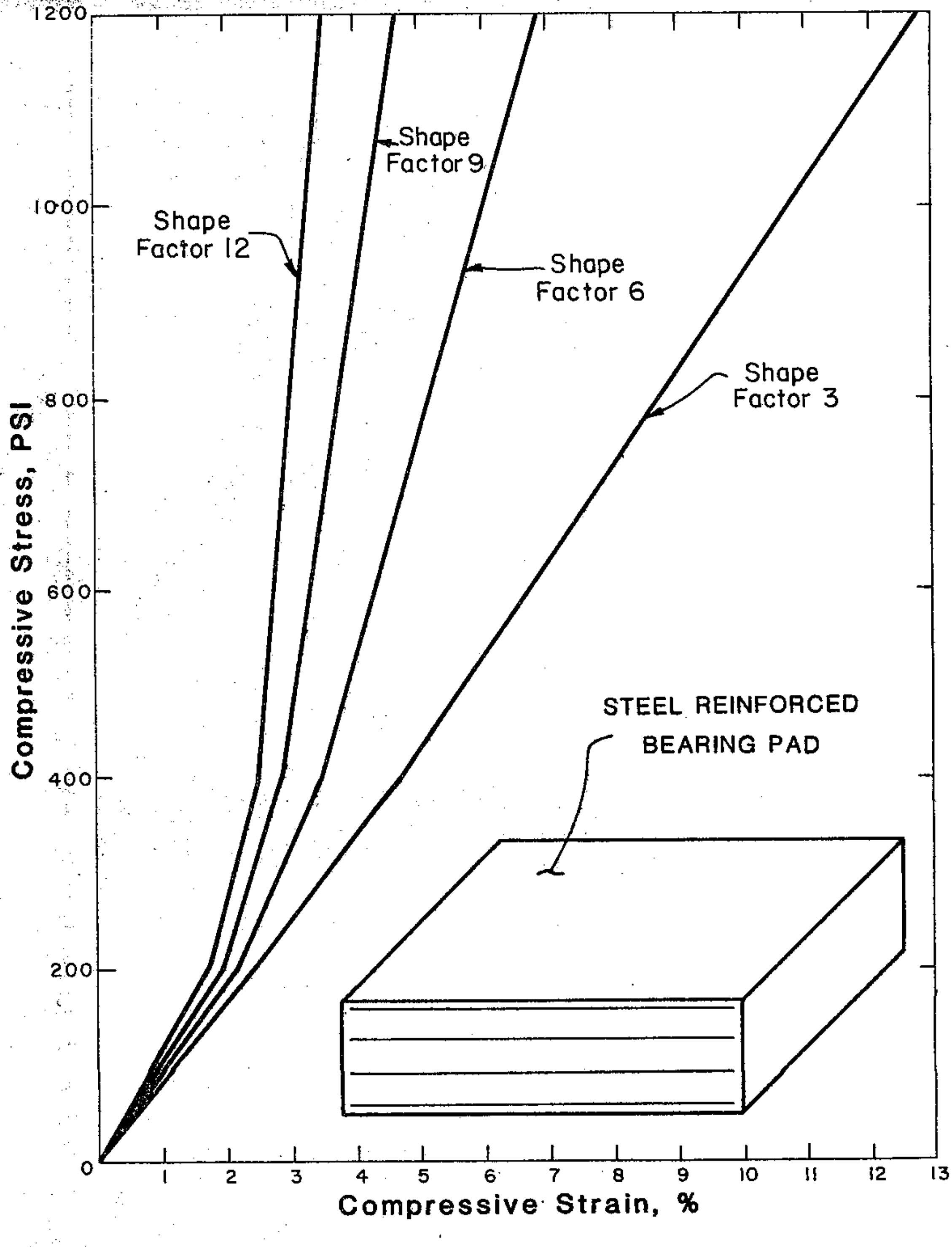
The fiberglass reinforced pads showed essentially no difference between the theoretical 50 and 60 durometer hardnesses, and again were combined as a single set of curves for design purposes.

When compared to the 1974 design curves, Figures 14 and 15 show slightly more compressive strain at the 800 psi level for all shape factors tested.



RECOMMENDED COMPRESSIVE STRESS-VS-STRAIN CURVES FOR FIBERGLASS REINFORCED BEARING PADS

FIGURE 14



RECOMMENDED COMPRESSIVE STRESS-VS-STRAIN CURVES FOR STEEL REINFORCED BEARING PADS

FIGURE 15

ULTIMATE COMPRESSIVE STRENGTH TEST

In order to develop adequate data relating to the maximum allowable compressive loads for use in reinforced elastomeric bearing pad design, several bearing pads were selected for testing to compressive failure.

Prior to the actual testing of the pads for ultimate load, it was necessary to estimate the loading that each pad would withstand. From the previous work done in 1974(1), we felt sure that the steel reinforced pads would fail as a result of yielding of the steel. Since the grade of steel used in the construction of the test pads was not specified for the 14 gage material used, a yield strength of 40,000 psi was assumed. The approximate ultimate load that each pad could withstand was then calculated utilizing a theoretical equation from Rejcha(2) in which the tensile stress in the bonded steel plate was assumed to be directly proportional to the compressive stress in the elastomer.

Based on a 14 gage steel plate thickness of 0.075 inch and a 40,000 psi yield strength, the resulting ultimate compressive stress in the elastomer was estimated to be 6,000 psi (assuming no failure due to bond) based on the following equation:

$$\text{Plate Stress} = \text{Elastomer Stress}\ \left(\frac{te}{ts}\right)$$

Where te = Elastomer thickness
ts = Steel thickness

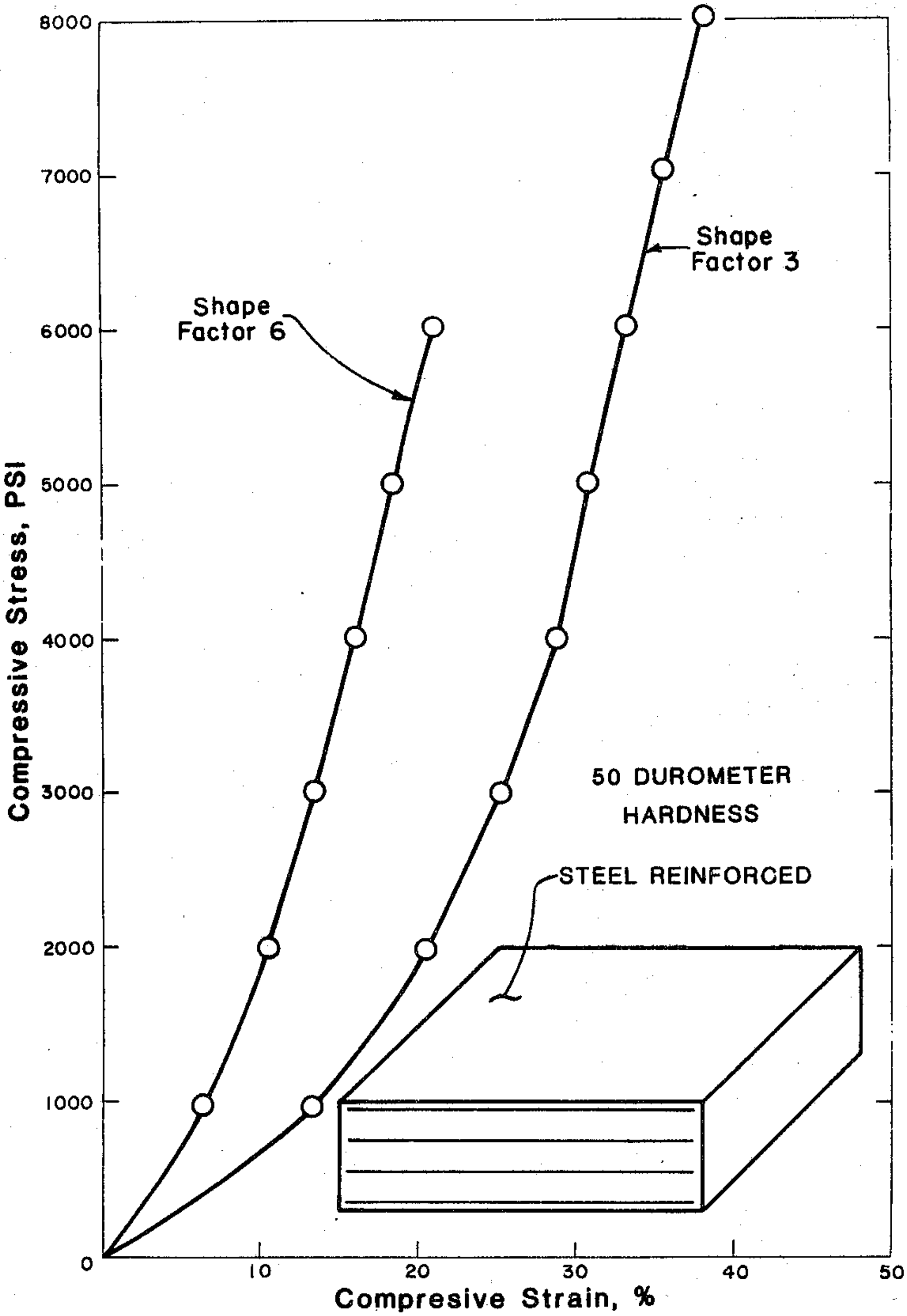
Due to the load limitations of our testing machine, only pads with a shape factor of 3 or 6 could be tested to these values.

Since the fiberglass reinforced pads had all failed in the range of 1,800 psi during the compressive stress vs strain testing, there was no need to conduct additional ultimate strength tests on these pads.

The testing procedure used during the ultimate compressive strength tests consisted of the same set up, rate of loading, and loading increments as used for the compressive stress vs strain test. Again the four dial indicators were used to measure deflection of the pad at each corner.

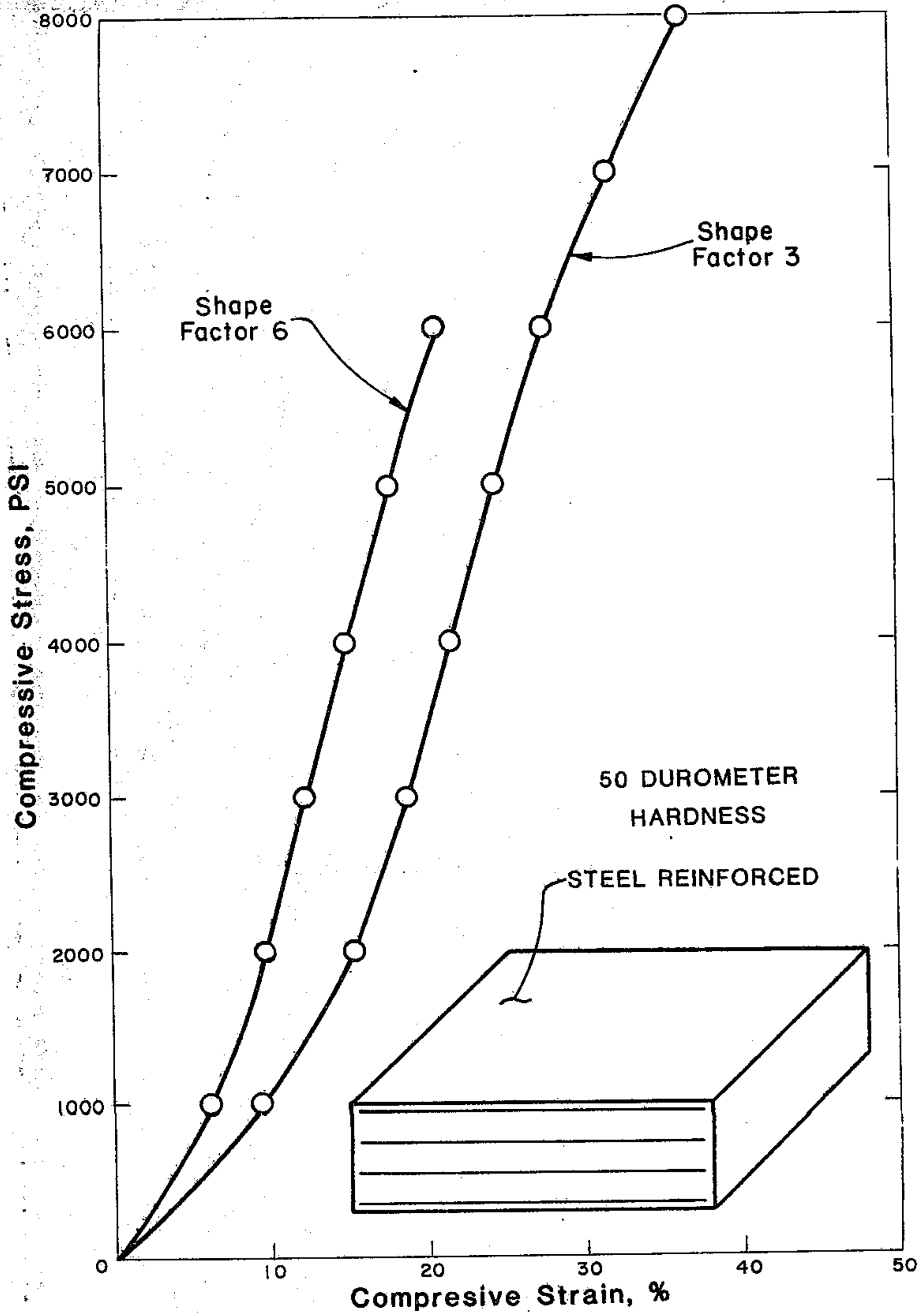
Test Results

Figures 16 and 17 show the ultimate stress vs strain curves for the steel reinforced pads tested from each supplier. As with the compressive stress vs strain curves, the biggest variation was with shape factor 3. The pads from supplier number 2 tended to be slightly stiffer than those from supplier number 1 but the average ultimate strength of pads furnished by both suppliers was very close (11,400 psi vs 11,000 psi).



ULTIMATE LOAD-VS-DEFLECTION
STEEL REINFORCED PADS
SUPPLIER No. 1

FIGURE 16



ULTIMATE LOAD VS DEFLECTION
STEEL REINFORCED PADS
SUPPLIER No. 2

FIGURE 17

Discussion

Although the ultimate strength curves for the two different suppliers were somewhat different, the mode of failure was the same, yielding and failure of the steel (see Figure 18). Inspection of the bearing pads during and following the loading showed no signs of failure due to loss of bond or failure of the neoprene itself.

Present Caltrans design criteria limits the combined dead load + live load on the bearing pad to 800 psi. Based on the results of these ultimate compressive strength tests, this 800 psi value would seem appropriate for the fiberglass reinforced pads (safety factor approximately 2:1). For the steel reinforced bearing pads, the 800 psi value would appear to be somewhat conservative when utilizing a 14 gage steel shim material.

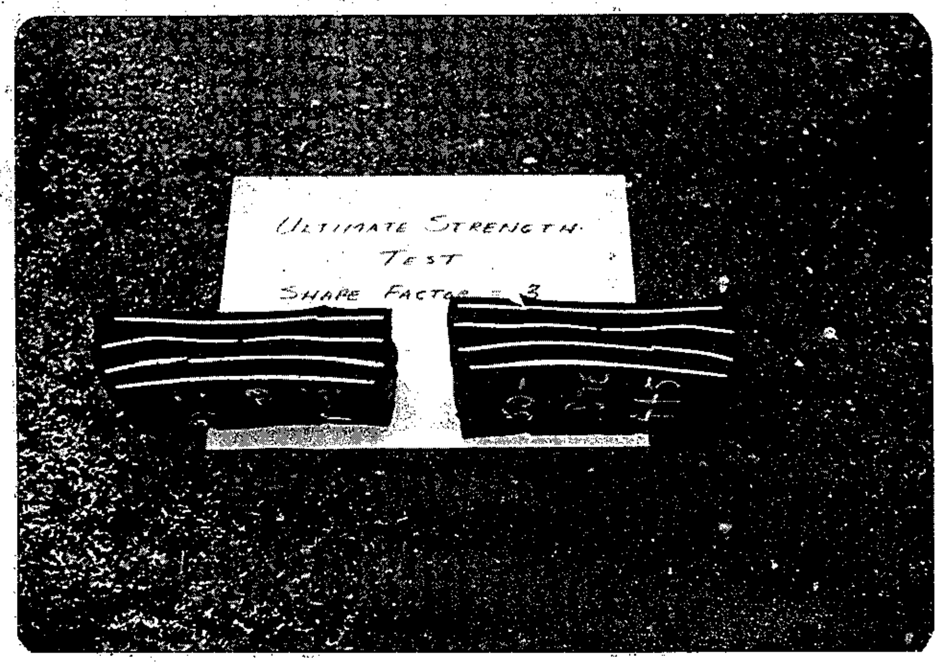


Figure 18. Failure of Steel Reinforced Bearing Pads

COMPRESSIVE CREEP TEST

From previous research associated with the 1974 study, it was found that compressive creep due to a static loading condition resulted in approximately 20% additional deflection at time = 10 years following an initial loading of 600 psi. At an initial loading of 1,000 psi, this percentage of additional deflection increased slightly to approximately 25% for the same time = 10 year period.

Since the possibility exists of increasing the allowable design criteria for compressive loading of steel reinforced pads, it was felt that creep characteristics should be examined at some elevated level which would be sure to include any increase in design loading recommendations. With this in mind, samples of steel reinforced pads with shape factors of 3, 6, 9 and 12 were selected for creep analysis at 2,000 psi compressive loadings.

For these creep tests, the same test apparatus described previously was used (see Figure 19). The test machine was programmed to hold a constant load during the duration of the creep test. Compressive deflections were again measured at each corner of the test pad and recorded versus time.

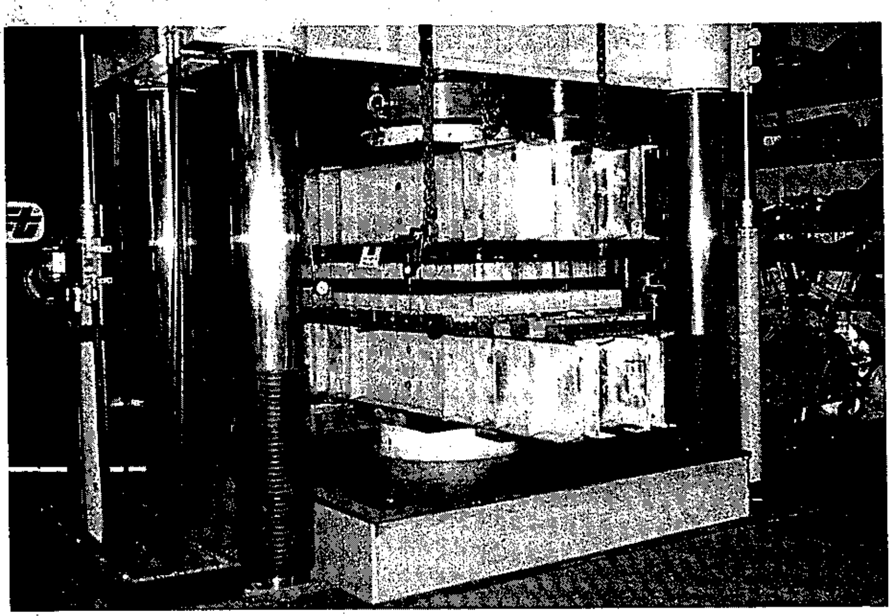


Figure 19. Test Setup For Creep Test

Creep specimens were all tested for a minimum of 100 hours.

Data recorded were reduced and presented in terms of percent of additional deflection in relation to the initial deflection.

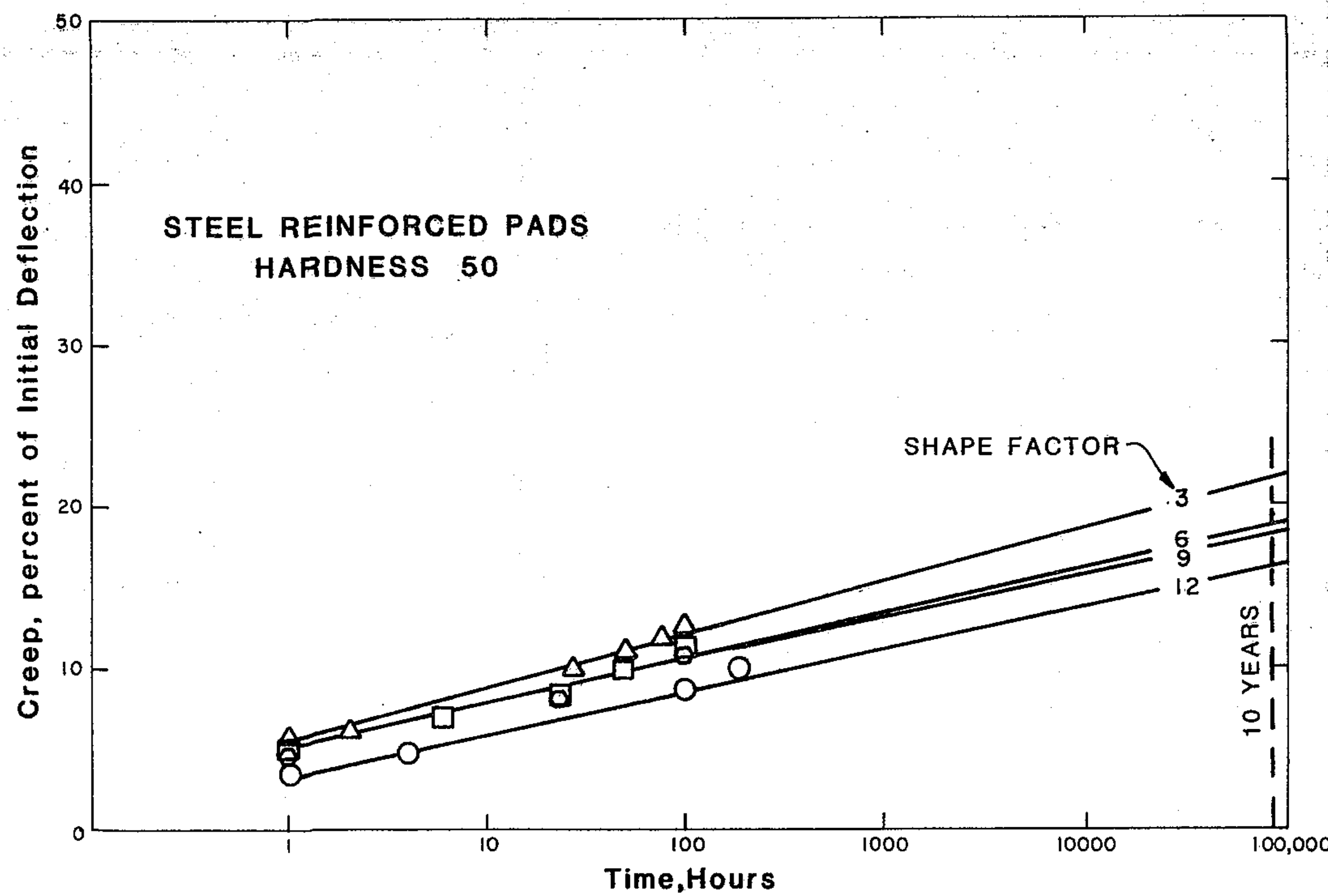
$$\% \text{ Creep} = \left[\frac{\text{Deflection at Time } t}{\text{Initial Deflection}} - 1\right] \times 100$$

Test Results

Figure 20 shows the percent of additional deflection following initial loading of 2,000 psi. For the purposes of estimating the long term deflection, a logarithmic scale was used to display the data. Based on these tests, 10 years of additional creep would result in approximately 20% additional deflection.

Discussion

These curves from Figure 20 indicate a slightly less percent of creep than those obtained by the 1974 study for steel reinforced pads. Because of the higher initial deflection when loaded to 2,000 psi vs the 1974 study at 1,000 psi, the total deflection of the pads will be more. However, the creep is based on the percent of additional deflection following the initial deflection. Therefore, although the loading is higher, the percent of additional deflection due to creep agrees very closely with the 1974 study. It would seem that, based on these predicted values, the effect of creep could be neglected from a design point of view for pad thicknesses less than four inches. For example, a bearing pad with a design thickness of four inches and shape factor of 3 would have an initial deflection of 0.5 inch at a 1,200 psi loading. The additional deflection due to sustained creep at the end of 10 years would amount to approximately 0.1 inch (0.5 x 20%), a minor amount.



CREEP UNDER 2000 PSI COMPRESSIVE STRESS

FIGURE 20

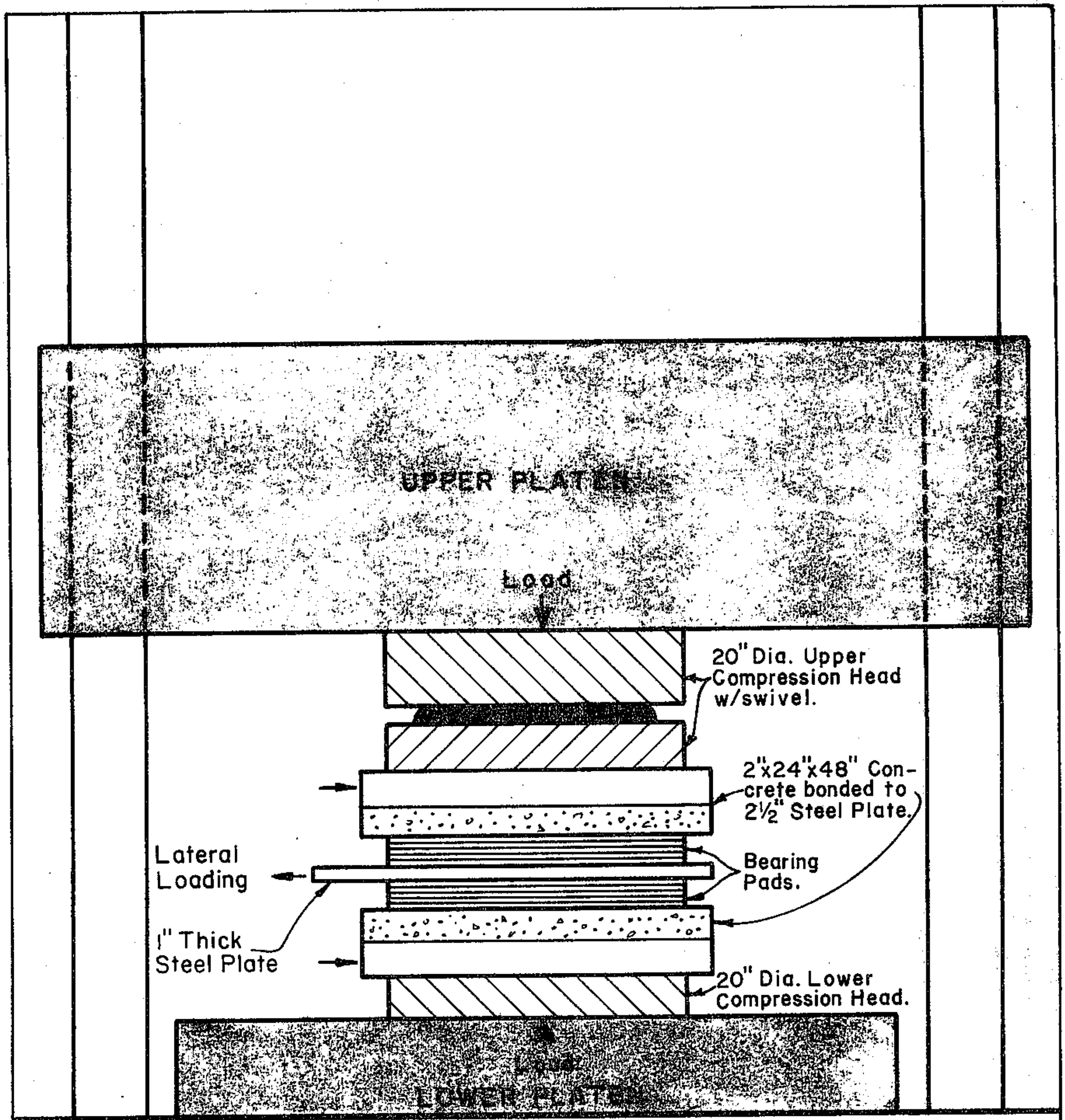
Initially, it was intended to look at creep for both steel and fiberglass reinforced pads for hardnesses of 50 and 60. However, based on the creep data that were generated by the 2,000 psi loading on steel reinforced pads and its general agreement with the earlier 1974 study, it was decided to eliminate creep testing of the fiberglass reinforced pads at 800 psi.

TRANSLATION TEST

From the previous work done in 1974, it was established that the shear modulus was not significantly dependent on the magnitude of compressive stress up to the testing limit of 800 psi. Since there have been recommendations, with regard to steel reinforced pads, to increase the allowable compressive stress to some value above the present criteria of 800 psi, additional testing was felt necessary at higher levels of compressive loads.

Three series of translation tests were conducted on steel reinforced pads with shape factors of 6 and 9 for both theoretical durometer hardnesses of 50 and 60. The compressive loads applied during the three test series were 800 psi, 1,000 psi and 1,200 psi.

The test apparatus used for these series of tests utilized a one-inch thick steel plate sandwiched between two identical steel reinforced bearing pad specimens. During the testing, the 1,000,000 pound testing machine was set to maintain a constant compressive load during the actual translation of the pads. Horizontal loads were applied by the use of a 120,000 pound capacity hydraulic jack (see Figures 21 and 22). Horizontal loads were measured by the use of a strain gage load cell which was mounted against the jack. The movement in the horizontal direction was monitored by two dial indicators located on either side of the ram approximately 24 inches apart (see Figure 22). Vertical displacement was also recorded by two dial indicators mounted off the test fixture.



TYPICAL TRANSLATION TEST

FIGURE 21

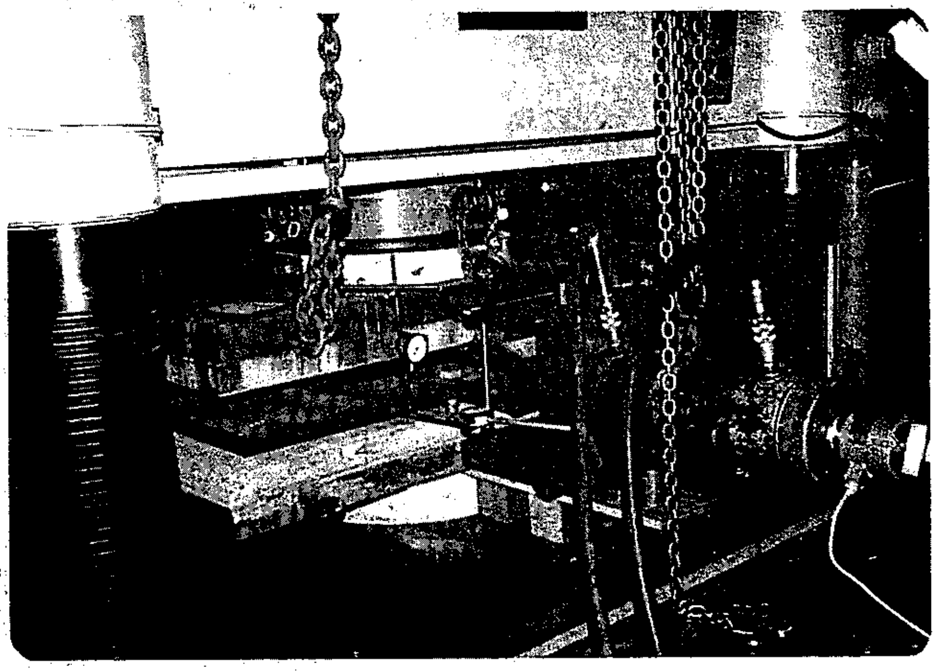


Figure 22. Translation Test Setup

After the compressive load was applied, the steel reinforced bearing pad specimens were translated horizontally at intervals of 10% of the total pad thickness (including reinforcement) up to a total translation of 2.0 inches (see Figure 23).

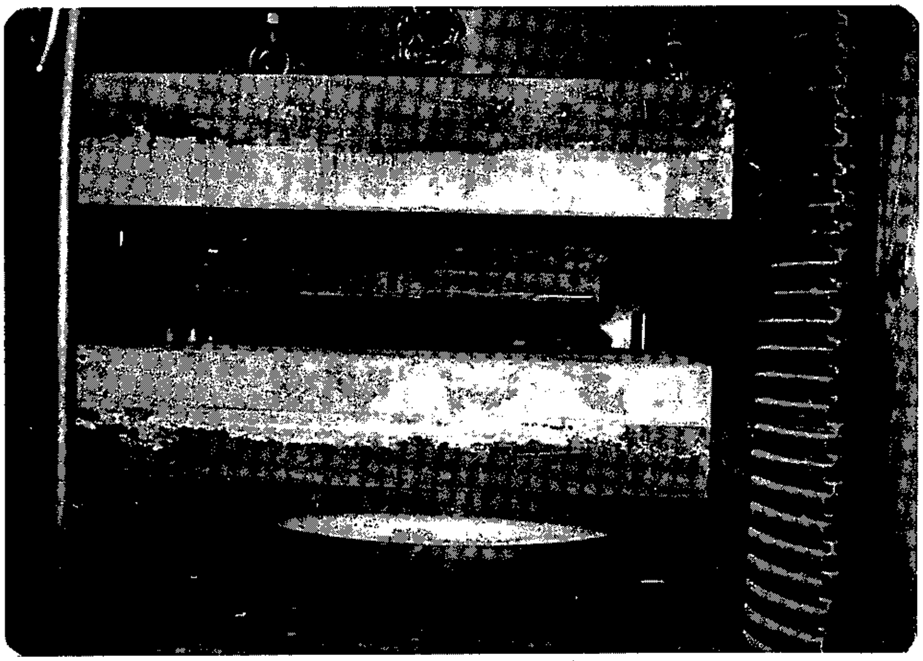


Figure 23. Bearing Pads During Translation Test

At each translation interval, the various horizontal loads and displacement readings were taken within 30 seconds to minimize the effect of additional movement due to creep.

Test Results

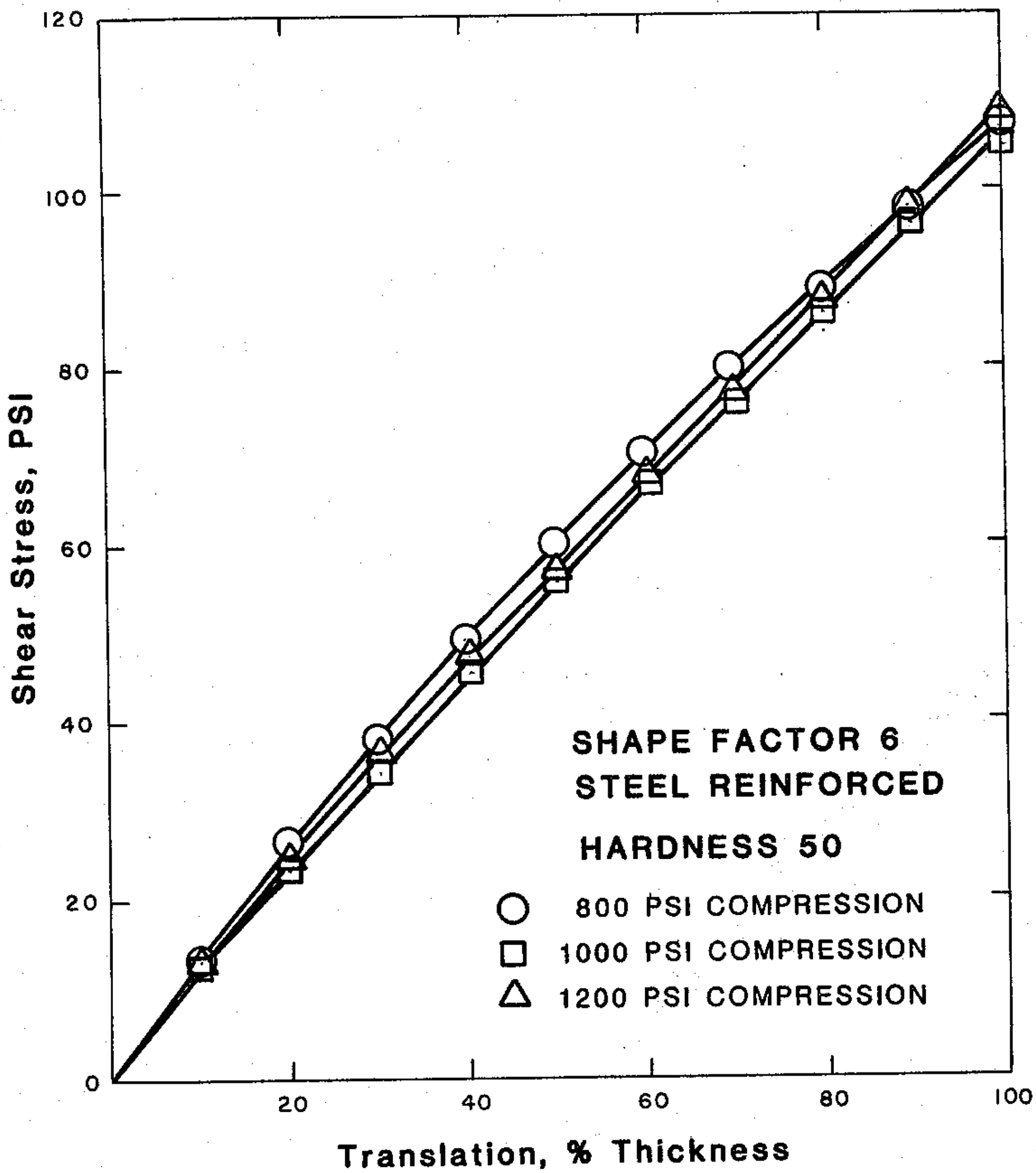
Figures 24, 25, 26 and 27 represent the shear stress vs translation for various shape factors and hardnesses tested.

From the curves, it is obvious that the variation in shear stress for the loads of 800, 1,000 and 1,200 psi at a given shape factor was minimal. As expected, the pads of hardness 50 exhibited a lower shear stress than the pads of hardness 60.

Discussion

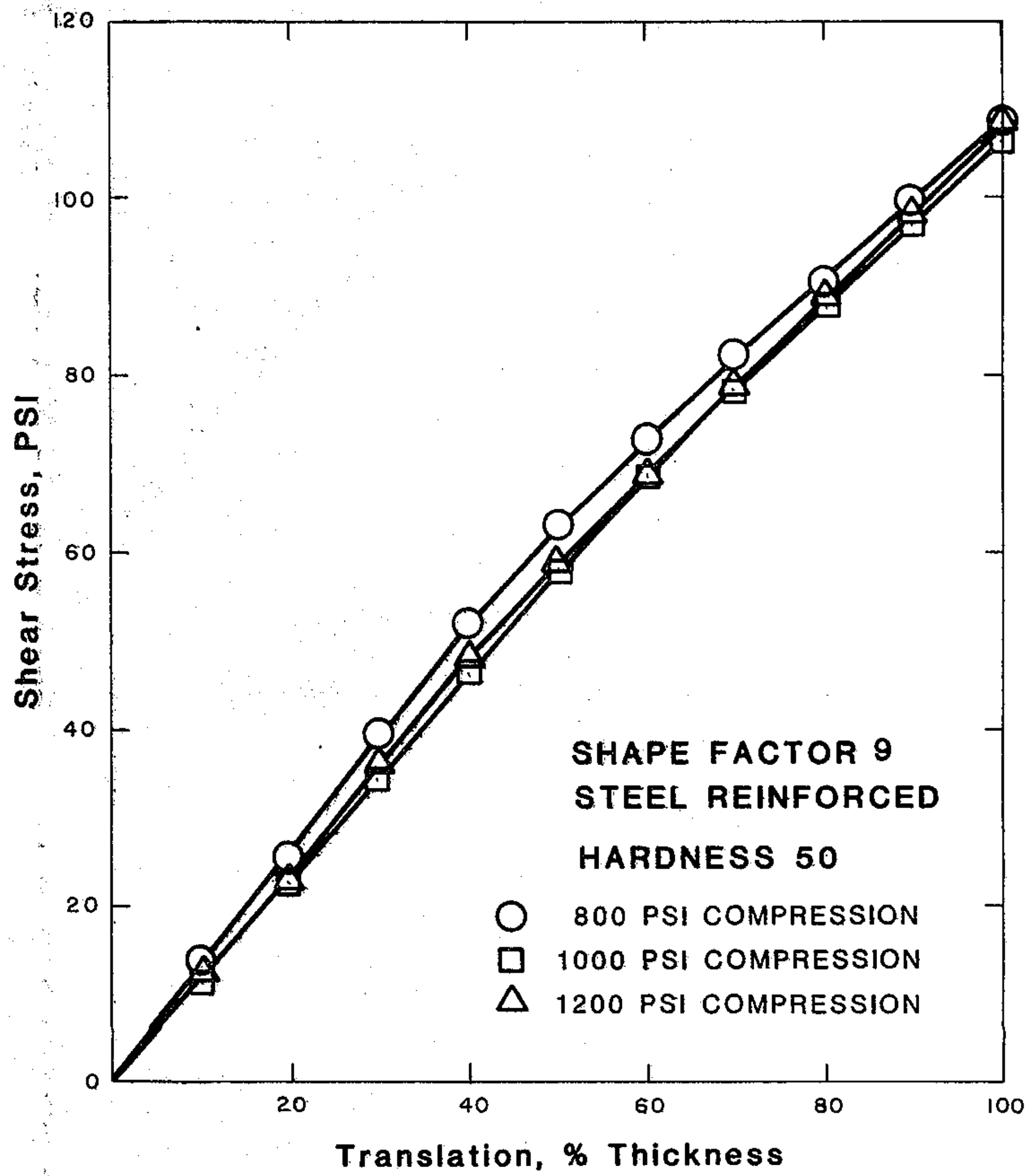
Of the steel reinforced elastomeric pads tested, none exhibited a great amount of curl at their edges when translated 100% of their thickness. This was felt to be due in part to the thicker (14 gage) steel reinforcement used in these bearing pads versus the 20 gage reinforcement used in the 1974 study.

No translation tests were conducted on the fiberglass reinforced pad at these higher levels of compressive stress due to the fact that the ultimate strength level (1,800 psi) did not warrant allowable compressive loads in excess of 800 psi.



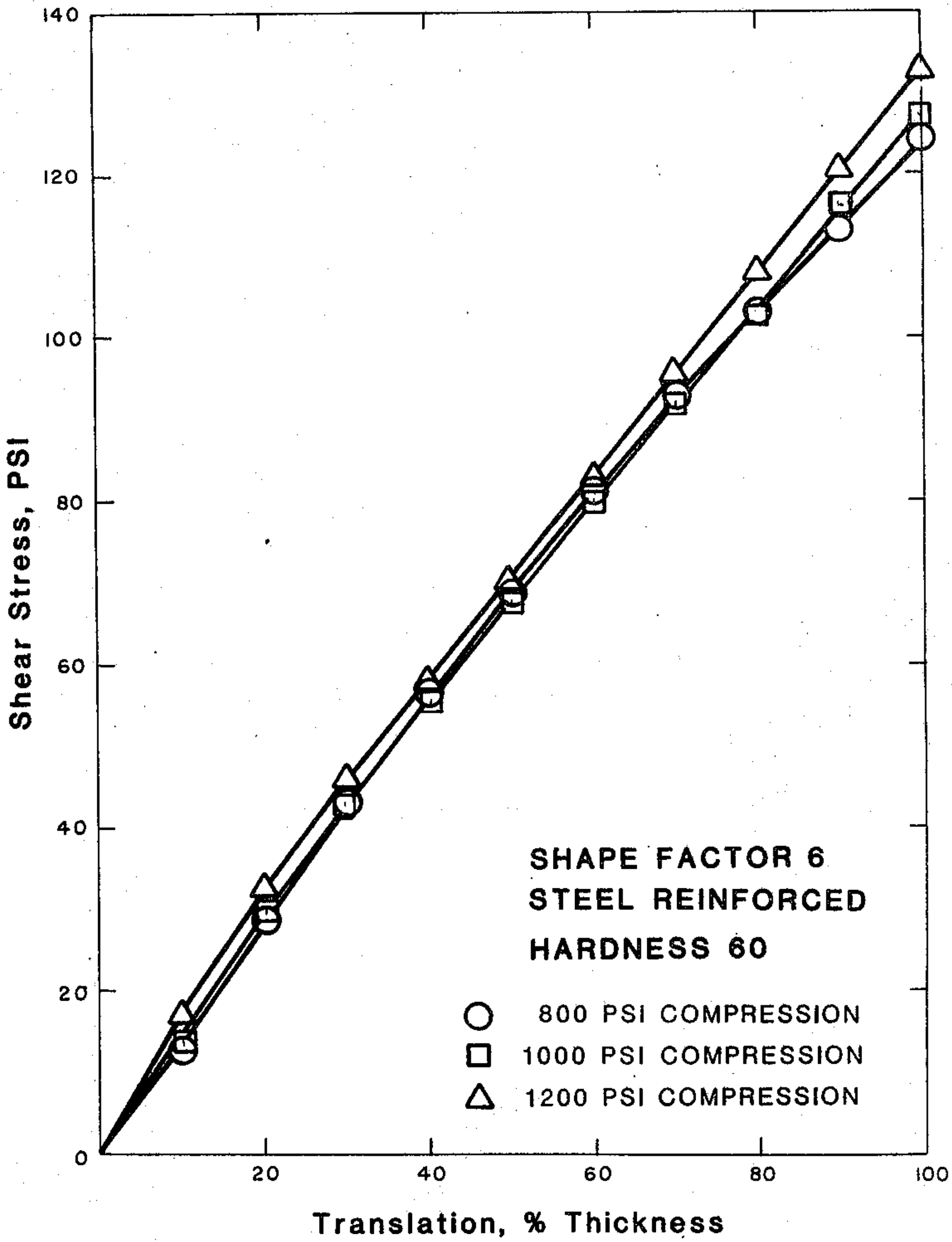
SHEAR STRESS VS TRANSLATION

FIGURE 24



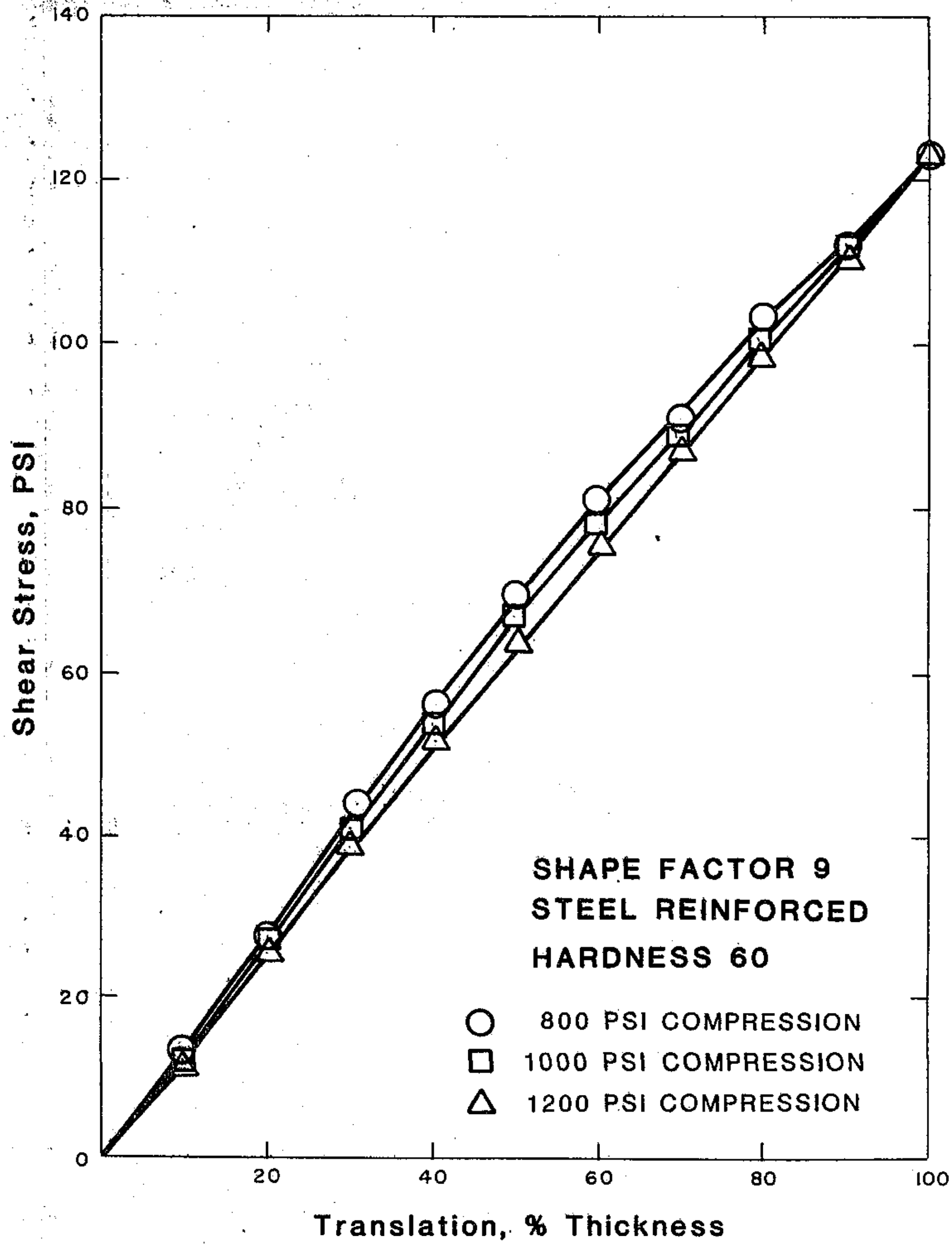
SHEAR STRESS VS TRANSLATION

FIGURE 25



SHEAR STRESS-VS-TRANSLATION

FIGURE 26



SHEAR STRESS-VS-TRANSLATION

FIGURE 27

The shear modulus at a lateral translation equal to 100% of the total pad thickness was approximately 125 for the pads with a durometer of 60, and 107 for the pads with a durometer of 50. These values are slightly higher than the 1974 study indicated but still within current Caltrans specifications. Both the 1974 study and this study used the total thickness of the bearing pad (including shim) in the calculation of shear modulus, G.

$$G = \text{Shear Stress} \times \frac{\text{Pad Thickness}}{\text{Pad Translation}}$$

In addition to these translation tests, conducted to evaluate the Shear Modulus at 800 psi, 1,000 psi and 1,200 psi compression, several steel reinforced pads with a shape factor of 3 were tested for compliance with California Test 663 at these levels of compression (see Appendix).

Test specimens were subjected to fatigue testing of 10,000 cycles at a translation of one-half the thickness of the elastomer in each direction. The testing speed was set at 4-1/2 inches per minute.

Inspection of the bearing pads during and following the 10,000 cycle test showed no evidence of deterioration of the elastomer or the bond between the elastomer and steel reinforcement.

REFERENCES

1. Crozier, W. F., Stoker, J. R., Martin, V. C. and Nordlin, E. F., "A Laboratory Evaluation of Full Size Elastomeric Bridge Bearing Pads," June 1974.

2. "Design of Neoprene Bridge Bearing Pads," E. I. duPont deNemours and Company, Inc., April 1959.

3. Rejcha, C., "Design of Elastomer Bearings," Prestressed Concrete Institute Journal, October 1964.

APPENDIX

Following is a summary of the test results of the physical properties of the elastomer based on samples taken from both the steel reinforced and the fiberglass reinforced bearing pads. These samples are representative of all pads tested. Physical testing was conducted in accordance with Caltrans Standard Specifications.

Physical Properties

Sample Number	Tensile PSI	Elongation %	Tear lbs/in	Hardness
50-6-1F	2520	626	246	49
50-6-2F	2910	636	270	50
50-6-3F	2806	603	274	49
60-6-1F	3064	593	267	55
60-6-2F	2514	633	199	54
60-6-3F	2905	550	252	56
50-6-1S	2500	670	218	50
50-6-2S	2635	710	224	50
50-6-3S	2660	650	213	52
60-6-1S	2490	600	216	54
60-6-2S	2280	550	231	55
60-6-3S	2623	556	209	55
50-9-1F	3363	630	263	52
50-9-2F	2997	657	270	52
50-9-3F	3223	630	275	54
60-9-4F	2976	627	252	53
60-9-5F	3180	643	291	55
60-9-6F	3310	683	232	56

turer or an independent testing agency.

Samples of the prefabricated joint seals, not less than 36 inches in length, will be taken by the Engineer from each lot of material. Samples will be selected at random from stock at the job site or at a location acceptable to the Engineer and the manufacturer. The samples shall be furnished for testing, with the Certificate of Compliance, 30 days in advance of proposed use.

(c) Joint Seal Assemblies.—Joint seal assemblies shall be furnished and installed in joints in bridge decks as shown on the plans and as specified in the special provisions.

51-1.12G Bearing Devices.—Bearing plates, bars, rockers, assemblies, and other expansion or fixed devices shall be constructed in accordance with the details shown on the plans and shall be hot-dip galvanized after fabrication. Structural steel, cast steel, and galvanizing shall conform to the provisions in Section 75, "Miscellaneous Metal," for those items.

The bearing plates shall be set level and the rockers or other expansion devices shall be set to conform to the temperature at the time of erection or to the setting specified.

When bearing assemblies or masonry plates are shown on the plans to be placed (not embedded) directly on concrete, the concrete bearing area shall be constructed slightly above grade and shall be finished by grinding or other approved means to a true level plane which shall not vary perceptibly from a straightedge placed in any direction across the area. The finished plane shall not vary more than 1/8 inch from the elevation shown on the plans.

When elastomeric bearing pads, preformed fabric pads, or asbestos sheet packing are shown on the plans, the concrete surfaces on which pads or packing are to be placed shall be wood float finished to a level plane which shall not vary more than 1/16 inch from a straightedge placed in any direction across the area. Said area shall extend at least one inch beyond the limits of said pads or packing. The finished plane shall not vary more than 1/8 inch from the elevation shown on the plans.

Where bearing assemblies or masonry plates are shown on the plans to be placed on mortar pads, they shall be placed in accordance with the provisions in Section 55-3.29, "Bearings and Anchorages."

51-1.12H Elastomeric Bearing Pads.—Elastomeric bearing pads shall conform to the requirements in these specifications and the special provisions.

Pads less than 1/2 inch in thickness shall be either laminated or all elastomer. Pads 1/2 inch or over in thickness shall be laminated. Stacking of individually laminated pads to attain thicknesses over 1/2 inch will not be permitted; however, cold bonding of individual laminated pads will be permitted providing the bond between the pads has a minimum peel strength of 20 pounds per inch when tested in accordance with Test Method No. Calif. 663.

Laminated pads shall consist of alternate layers of elastomer and metal or fabric reinforcement bonded together. The top and bottom layers of reinforcement shall be uniformly covered with a maximum of 1/8 inch of elastomer. The edges of metal reinforcement shall be fully coated with elastomer not more than 1/4 inch in thickness.

Laminated pads shall have reinforcement every 1/2 inch through the entire thickness. The reinforcement shall be parallel to the top and bottom surfaces of the pad. Variations in the location of the reinforcement in excess of 1/8 inch from its theoretical location shall be cause for rejection. The total out to out thickness of a pad shall not be less than the thickness shown on the plans nor more than 1/4 inch greater than that thickness.

Pads of all elastomer or with fabric reinforcement may be cut from large sheets. Cutting shall be performed in such a manner as to avoid heating of the material and to produce a smooth edge with no tears or other jagged areas and to cause as little damage to the material as possible.

The bond between elastomer and metal or fabric shall be such that when a sample is tested for separation, it shall have a minimum peel strength of 30 pounds per inch when tested in accordance with Test Method No. Calif. 663.

Metal reinforcement shall be rolled mild steel sheets not less than 0.036–inch in nominal thickness.

Fabric reinforcement shall be woven from 100 percent glass fibers of "E" type yarn with continuous fibers. The minimum thread count in either direction shall be 25 threads per inch. The fabric shall have either a crowfoot or an 8 Harness Satin weave. Each ply of fabric shall have a breaking strength of not less than 800 pounds per inch of width in each thread direction when 3–inch by 36–inch samples are tested on split drum grips. Fabric reinforcement shall be single ply at top and bottom surfaces of the pad and double ply within the pad. The bond between double plies shall have a minimum peel strength of 20 pounds per inch.

The sole polymer in the elastomeric compound shall be neoprene and shall be not less than 60 percent by volume of the total compound.

The elastomer, as determined from test specimens, shall conform to the following:

Test	*ASTM Designation*	*Requirement*
Tensile strength, psi	D 412	2,250 Min.
Elongation at break, percent	D 412	350 Min.
Compression set, 22 hrs. at 158° F., percent	D 395 (Method B)	25 Max.
Tear strength, pounds per inch	D 624 (Die C)	180 Min.
Hardness (Type A)	D 2240 with 2 Kg.wt.	55 ± 5
Ozone resistance 20% strain, 100 hrs. at 100° ± 2° F.	D 1149 (except 100 ± 20 parts per 100,000,000)	No cracks
Low temperature stiffness, Young's Modulus at —30° F., psi.	D 797	5,000 Max.
Low temperature brittleness, 5 hrs. at —40° F.	D 736-54T	Passed

After accelerated aging in accordance with ASTM Designation: D 573 for 70 hours at 212° F. the elastomer shall not show deterioration changes in excess of the following:

Tensile strength, percent	– 15
Elongation at Break, percent	– 40 (but not less than 300% total elongation of the material)
Hardness, points	+ 10

Specimens tested in accordance with Test Method No. Calif. 663 for 10,000 cycles at 800 pounds per square inch and 1/2 t (t = total thickness of elastomer) translation, shall show no indication of deterioration of elastomer or bond between elastomer and metal or fabric reinforcement laminations. The testing speed will not exceed 4 1/2 inches per minute.

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer, and fabric (if used), in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of tests performed by the manufacturer upon samples of the elastomer and fabric to be used in the pads.

Test specimens for tensile strength, elongation, tear strength, peel strength, and ozone resistance will be taken from production run pads by the Engineer, and will be prepared for testing by cutting and grinding. A fabric sample not less than 36 inches by 45 inches shall be submitted for testing from each new lot of fabric used in manufacturing bearing pads. A sample pad not less than 6 inches by 12 inches in size shall be submitted for testing from each lot of pads or batch of elastomer to be furnished, whichever results in the greater number of samples. The samples will be selected at random at the point of manufacture or, at the option of the Contractor, at the job site. Samples taken at the job site shall consist of complete pads as detailed on the plans, and the Contractor shall furnish additional complete pads to replace those taken for testing. Pads shall be available for sampling 3 weeks in advance of intended use. All sample pads for testing shall be furnished by the Contractor at his expense.

51–1.13 **Bonding.**—Construction joints shall be made only where located on the plans or shown in the placing schedule, unless otherwise approved by the Engineer.

Horizontal construction joints may be made without keys, except when keys are shown on the plans. Surfaces of fresh concrete at horizontal construction joints shall be rough floated sufficiently to thoroughly consolidate the concrete at the surface without completely removing surface irregularities.

All construction joints shall be cleaned of surface laitance, curing compound and other foreign materials before fresh concrete is placed against the surface of the joint. Abrasive blast methods shall be used to clean horizontal construction joints to the extent that clean aggregate is exposed. All construction joints shall be flushed with water and allowed to dry to a surface dry condition immediately prior to placing concrete.

When existing structures are to be modified, construction joints between new and existing concrete shall be cleaned and flushed as specified herein for horizontal joints.

In case of emergency, construction joints shall be made as directed by the Engineer. When it is necessary to make a joint because of an emergency, additional reinforcing steel shall be furnished and placed across the joint as directed by the Engineer. Such additional reinforcing steel shall be furnished and placed by the Contractor at his expense.

When new concrete is shown on the plans to be joined to existing concrete by means of bar reinforcing steel dowels grouted in holes drilled in the existing concrete, the diameter of the holes shall be the minimum needed to place the grout and the dowel. The grout shall consist of a neat cement paste. Immediately prior to placing the dowels, the holes shall be cleaned of dust and other deleterious material and sufficient grout placed in the holes so that no voids remain after the dowels are inserted. Any dowels or grout which fail to bond or are damaged before the new concrete is placed shall be removed and replaced.

51–1.135 **Mortar.**—Mortar shall be composed of portland cement, sand, and water proportioned and mixed as specified in this Section 51–1.135.

Mortar shall be furnished and placed in recesses and holes, on surfaces, under structural members, and at other locations specified in these specifications, the special provisons or shown on the plans.

The proportion of cement to sand, measured by volume, shall be one to 2 unless

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California Test 663
1978

METHOD OF TESTING BRIDGE BEARING PADS

PART I. DETERMINATION OF COEFFICIENT OF FRICTION AND FATIGUE LIFE

A. SCOPE

The procedures to be used for the determination of the fatigue life and coefficient of friction or internal shear resistance of various bearing pad assemblies such as bronze, elastomeric, TFE (Teflon), etc., are described in this Part I.

B. TESTING APPARATUS AND ACCESSORIES

1. Expansion bearing pad fatigue testing machine. (See photograph and schematic drawing, Figures 1 and 2.)
2. Acetone
3. Stop watch
4. SR-4 strain indicator
5. 6-inch steel scale graduated in 1/100 of an inch.

C. TEST RECORD FORM

Use work card, Form T.L.-6028, for recording test data.

D. SPECIMEN PREPARATION

1. Clean all test specimens and both platens so that they are free of any foreign substances such as dust, grit, moisture, etc., except for the lubricants used in conjunction with the bronze specimens such as oil, grease, etc. Cut the elastomeric specimens to size (standard size 6″ x 6″) and wipe clean. File smooth any rough edges on the bronze specimens and wipe clean. Use acetone to clean the bearing surfaces of TFE (Teflon) bonded specimens only.

E. TEST PROCEDURE

1. After the specimen has been centered on the lower platen of the fatigue machine, screw the eight platen leveling rollers far enough into the platen so that they do not contact the vertical guide plates.
2. Zero in the strain indicator.
3. Apply vertical load by operating valves #1 and #2.
4. Then adjust valve #6 to maintain the required pressure as read on gage #2.
5. At this time the loading platens should be parallel; check with steel scale. If loading heads are not parallel, unload and repeat the loading procedure.
6. Remove the "at rest" shims and screw the eight platen leveling rollers finger tight against the guide plates to maintain platen stability.
7. Operate the top loading platen using the following procedure:
   a. Start hydraulic pump (start button).
   b. Open valve #5 all the way and then adjust valve #4 to maintain the proper testing speed. Note: Valve #5 must be opened before speed can be adjusted by valve #4.
   c. Adjust the testing speed by the use of a stop watch.
   d. Measure the horizontal load by use of the SR-4 strain indicator.
   e. The pressure indicated on gage #3 is controlled by valve #7. The function of valve #7 is to control the pressure applied to the horizontal ram.
8. At the end of the test period, stop and unload the machine by reversing the loading steps.

F. HORIZONTAL FORCE MEASUREMENTS

During the course of the test, record the strain gage readings to determine the horizontal force.

1. Take static coefficient of friction readings at the instant of impending motion or slip between the surfaces in question. For flexible backed TFE (Teflon) bearings, measure strain at the point of maximum displacement.
2. Obtain kinetic coefficient of friction readings by taking the average reading while surfaces are sliding. Do this in both directions of movement.

G. CALCULATIONS

$f = F/N$

Where:

F = Horizontal force due to friction or internal shear resistance (lbs).

N = Normal force (lbs).

f = Coefficient of friction

f_s = static

f_k = kinetic

Determine "F" from the strain gage indicator readings by use of calibration plot I (Figure 3). Determine N from gage #2 (Figure 2) by use of calibration plot II (Figure 4).

H. REPORTING RESULTS

1. Report the following test results on test report Form T.L. 6028.

a. Maximum static coefficient of friction.

b. Average static coefficient of friction.

c. Average kinetic coefficient of friction.

d. Remarks concerning the specimen's appearance after completion of test, excessive wear, delamination, etc.

The "The maximum friction coefficient" as determined on Form T.L.-6028 is defined as the highest coefficient as averaged over any 50 cycles of the test.

The "Average friction coefficient" is defined as the average of at least 5 and not more than 10 readings taken between 2,000 and 8,000 cylces. These readings shall be taken at intervals of not less than 500 cycles apart.

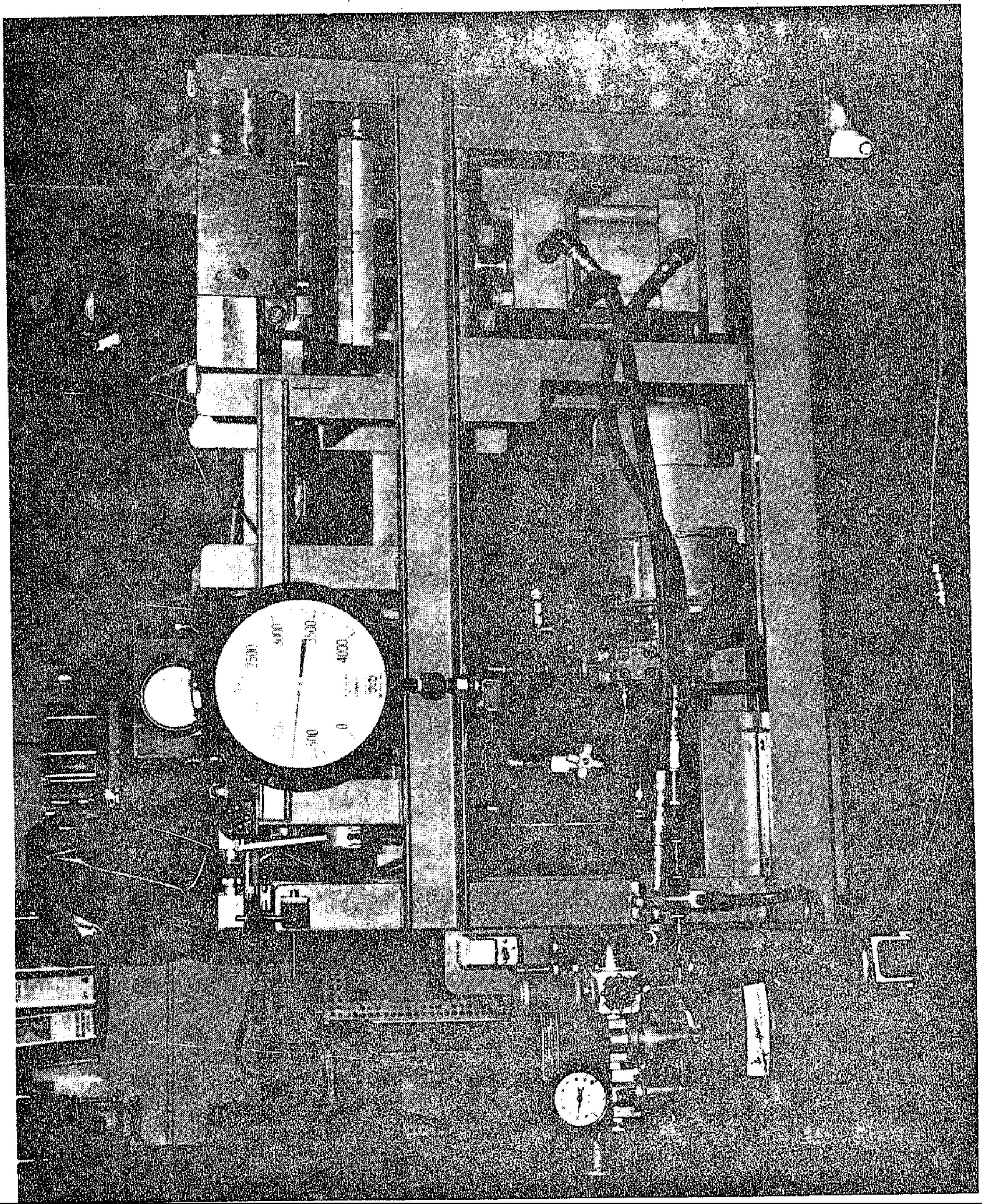


FIGURE 1

SCHEMATIC DIAGRAM OF FATIGUE TESTING MACHINE

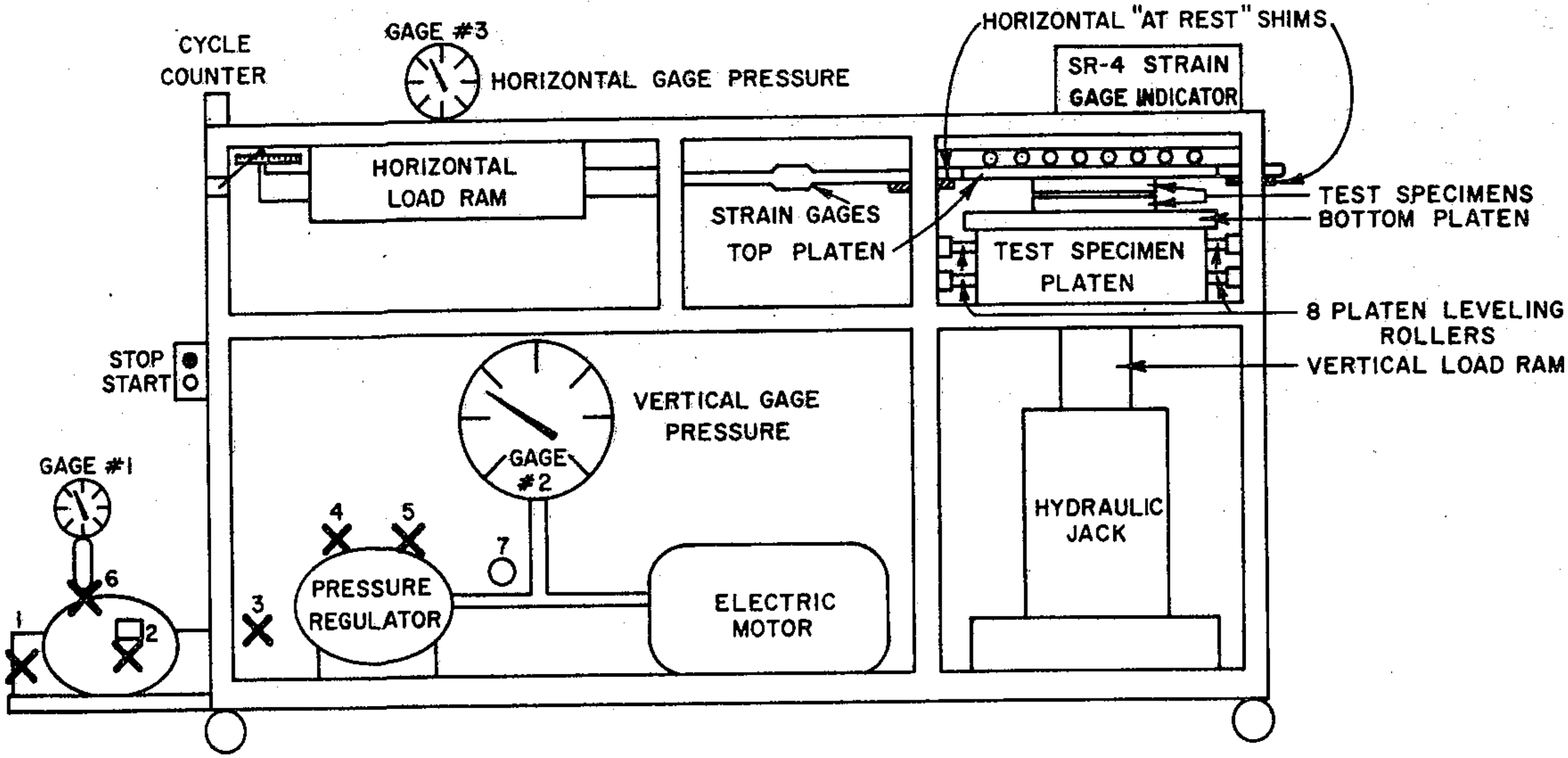


FIGURE 2

BEARING PAD FATIGUE TESTING MACHINE

STRAIN GAGE CALIBRATION CURVE

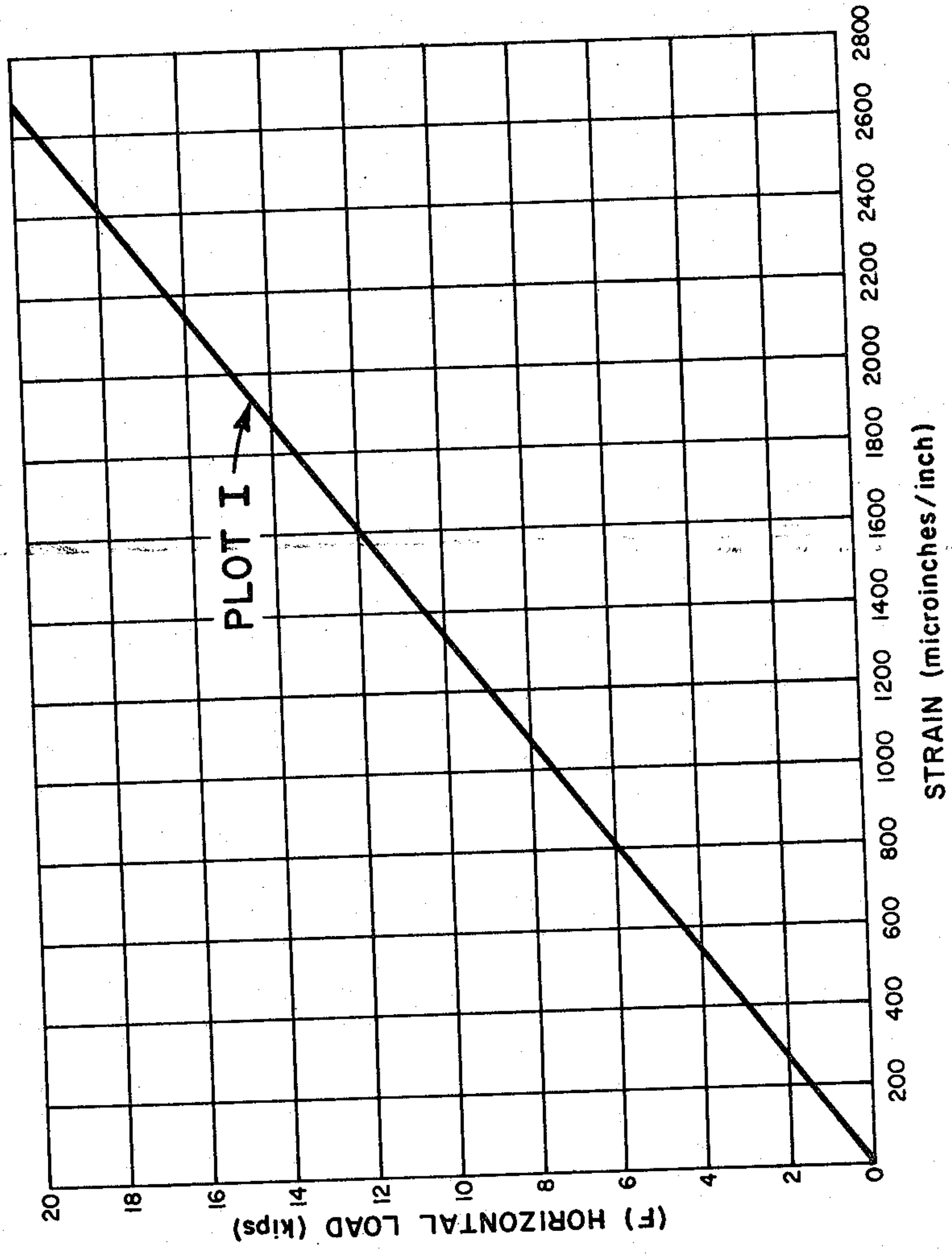


FIGURE 3

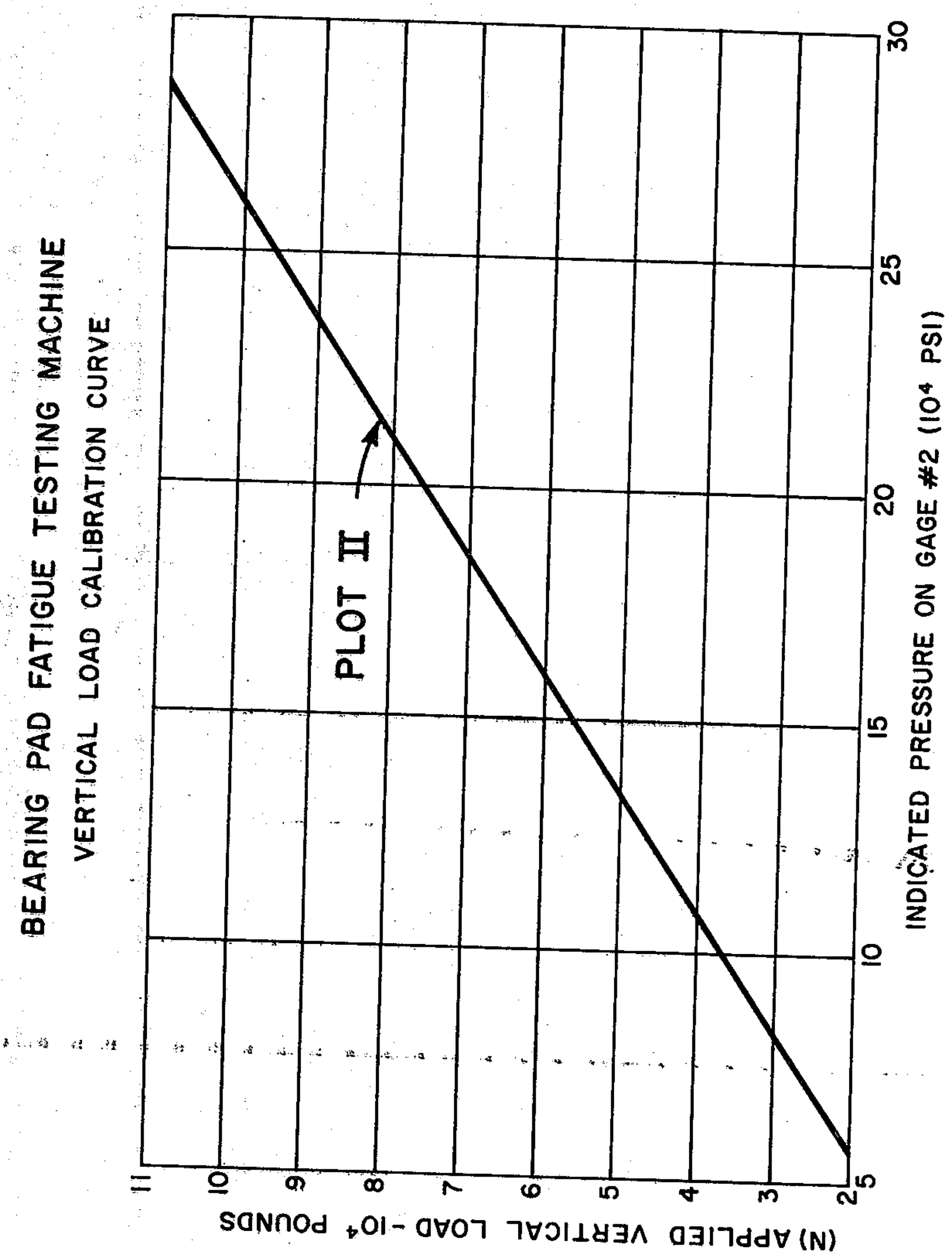

BEARING PAD FATIGUE TESTING MACHINE
VERTICAL LOAD CALIBRATION CURVE
PLOT II
INDICATED PRESSURE ON GAGE #2 (10⁴ PSI)
5
10
15
20
25
30
(N) APPLIED VERTICAL LOAD - 10⁴ POUNDS
2
3
4
5
6
7
8
9
10
11

FIGURE 4

TRANSPORTATION LABORATORY

FATIGUE AND COEFFICIENT OF FRICTION TEST DATA SHEET

TYPE: ______________________

SIZE: ______________________

DATE: ____________ LOAD: ____________

STROKE: SPEED:

DRAWING OF SPECIMEN

CYCLES	SPEED INCHES/ MINUTE	+ READING	− READING	MOVING AVERAGE	GAGE PRESSURE	N KIPS	+f KIPS	−f KIPS	MOVING f KIPS	+u	−u	THICKNESS INCHES	REMARKS

T.L.-6028 (Orig. 11/66)

FIGURE 5

PART II. DETERMINATION OF PEEL STRENGTH

A. SCOPE

The procedures to be used in determining the peel strength of elastomer bonded to metal or fabric reinforcement for elastomeric bearing pads are described in this Part II.

B. TEST APPARATUS AND ACCESSORIES

1. A testing machine which can measure loads up to 100 pounds with an accuracy of plus or minus one percent and a platen speed of 2 ± 0.2 inches per minute.
2. Rubber grips with jaws at least one inch wide. The grips shall be capable of firmly gripping the specimen without slippage during the testing.
3. A saw capable of cutting smoothly through elastomeric bearing pads with metal or fabric reinforcement.

C. SPECIMEN PREPARATION AND TESTING

1. Cut a one inch section (full thickness) off one side of the bearing pad sample as shown in Figure 5a. The minimum length shall be six inches.
2. Cut the section into test specimens as shown in Figure 5b.
3. Initiate peeling by neatly cutting neoprene back to neoprene-reinforcement interface. See Figure 5c.
4. Initiate uniform peeling by pulling on specimen. Separate the specimen a sufficient distance to permit clamping in the grips of the machine.
5. Install the specimen in the grips of the testing machine as shown in Figure 6. Care should be used in installing the specimen symmetrically so that the tension is applied uniformly. The grips shall concentrically maintain the specimen in a vertical direction during testing.
6. Apply the load at a uniform rate of 2 ± 0.2 inches per minute for a distance of at least two inches.
7. Determine and record the peel strength in pounds per inch. Peel strength is defined as the average load recorded on the testing machine when the specimen is slowly and uniformly peeled without snagging or binding.

D. REPORTING OF RESULTS

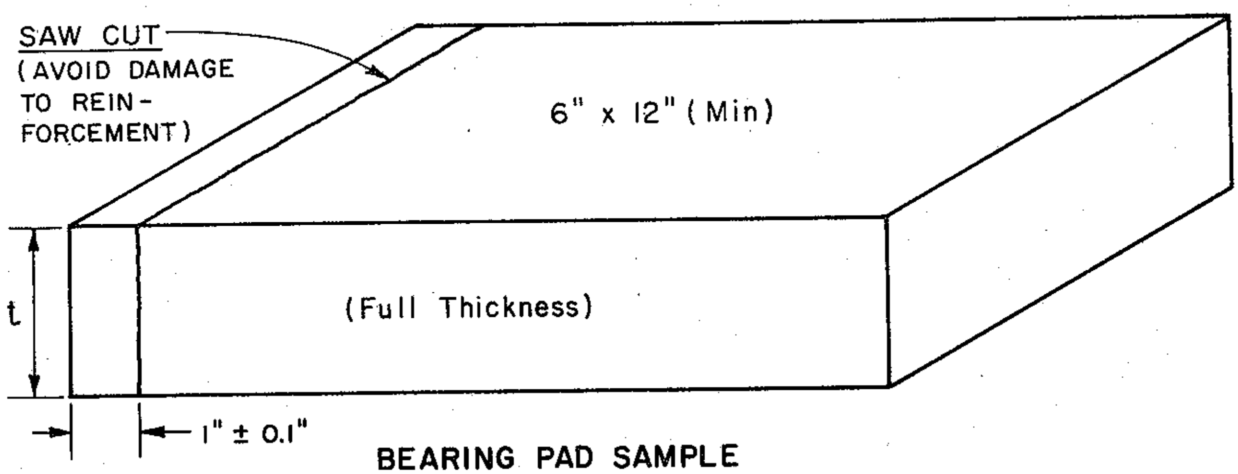
Document results of tests with appropriate comments and notations on Form T.L.-610. Report results in formal form (as complying or not complying with specifications) on Form T.L.-6039.

PART III. DETERMINATION OF THE PHYSICAL PROPERTIES OF BRIDGE BEARING PADS

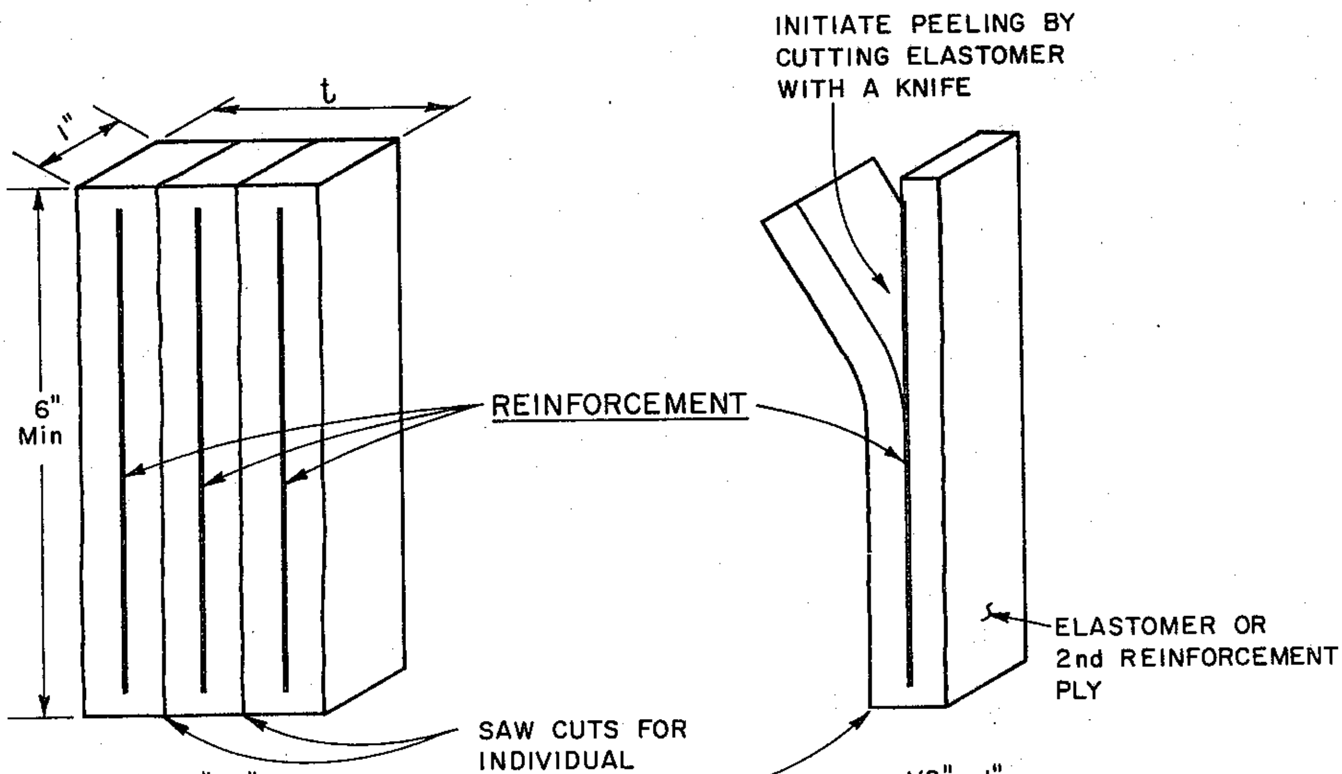
Except as shown in Part I and Part II, the other physical properties of bridge bearing pads shall be determined in accordance with the procedures as outlined in the appropriate American Society for Testing and Materials (ASTM) specifications or the American Association of State Highway Transportation Officials (AASHTO) specifications, as specified in the Standard Specifications.

REFERENCE
California Standard Specifications
End of Text (10 pgs) on Calif. 663

SPECIMEN PREPARATION



BEARING PAD SAMPLE
3/8" = 1"
(a)



1/2" = 1"
(b)

1/2" = 1"
(c)

FIGURE 5

PEEL TEST

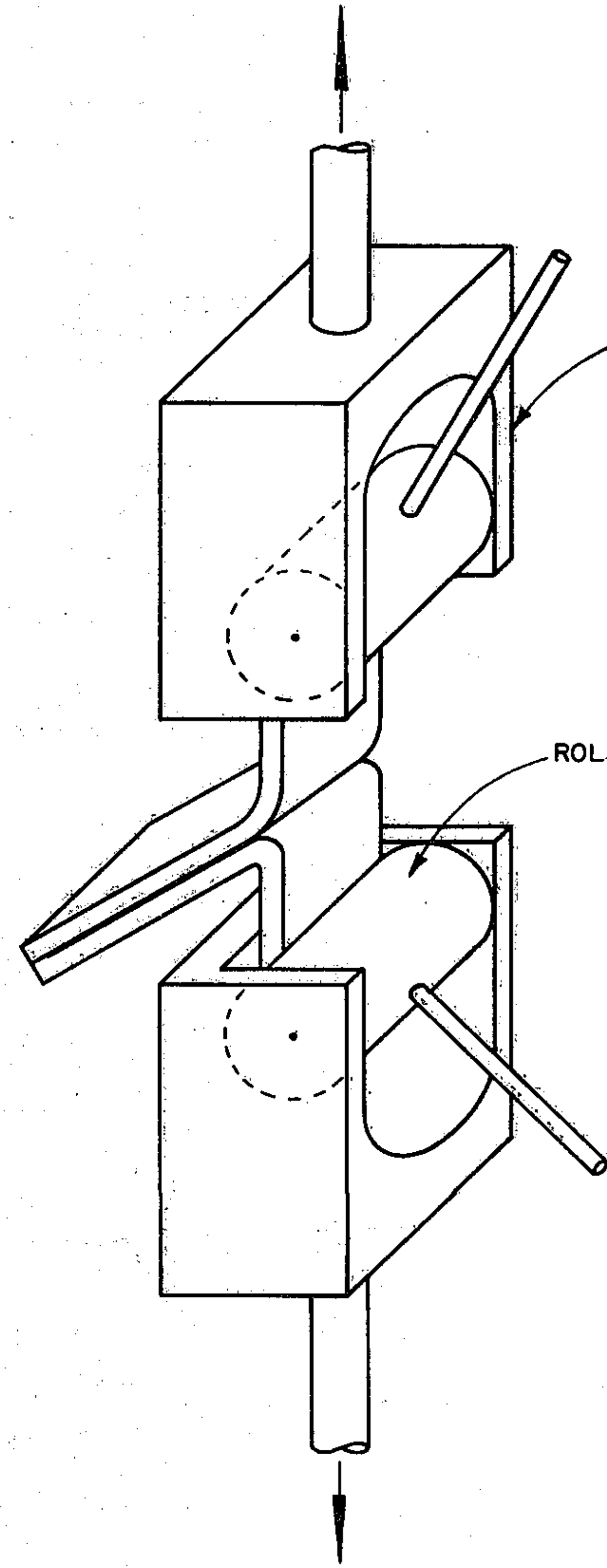


FIGURE 6